A PRELIMINARY ASSESSMENT OF THE LIKELY ENVIRONMENTAL IMPACTS OF TWO PROPOSED HYDRO-ELECTRIC SCHEMES ON THE ZAMBEZI RIVER, ZIMBABWE

by

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ABSTRACT

This report seeks to provide a synthesis of knowledge relating to two environments on the Zimbabwean side of the Zambezi River in order that the likely environmental impacts of proposed hydro-electric schemes might be assessed. Although the report does not constitute a Final Environmental Impact Statement, it discusses likely impacts in physical, biological and socio-economic fields, and the ways in which the overall study might be developed are outlined. The report has been produced under the auspices of the Natural Resources Board of Zimbabwe.

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PREFACE

I have compiled this report while employed as a Research Fellow at the University of Zimbabwe, with funding provided by the Zimbabwean Department of Natural Resources. Being a very broad investigation, it has involved the input of information, given either verbally or in writing, from a number of specialists; such information is referenced as clearly as possible in the text. I have attempted to check each section with the relevant specialists, but any errors or distortions are mine.

This is the most comprehensive Environmental Impact Assessment attempted in Zimbabwe. It is hoped that it will lead to further work on the likely environmental effects of the proposed Zambezi hydro-electric schemes, and it should provide information for the planning of alternative uses of the areas under consideration.

The study would not have progressed far without the willing participation of the consultant specialists (listed elsewhere). I also owe a great debt of gratitude to my parents in the preparation of the report; my mother, Flo du Toit, did the typing and my father, Fred du Toit, lettered the maps and diagrams that I had prepared, and both gave general advice. Robyn Haney also helped at this stage of the investigation. I must single out Gerald Pope and Tom Muller of the Zimbabwean National Herbarium for their good company on rather arduous fieldtrips. John Barkham and Mike Cockerell (International Union for Conservation of Nature and Natural Resources) plunged into the investigation with enthusiasm during their short stays in Zimbabwe. Members of the Zambian Wildlife Conservation Society and the University of Zambia were most hospitable during a visit to Lusaka. Mr. Desmond Lovemore, Director of Natural Resources, kept wheels turning and Prof. Malcolm Blackie, of the Department of Land Management at the University of Zimbabwe, provided me with an office and secretarial assistance. Tony Ferrar, previously with the Department of National Parks and Wildlife Management, helped clear the way at the

start of the investigation, and I benefited from the balanced scientific judgement of Dave Cumming, of the same department. Prof. Richard Fuggle attended to my academic requirements and gave up some of his valuable time to visit Zimbabwe and advise on my work. Gordon Allison, Chief Civil Engineer of the Central African Power Corporation, proved that engineers can cooperate with ecologists. John Stanning was a helpful colleague throughout.
To numerous other people who helped in one way or another, thank you.

1 INTRODUCTION

1.1 BACKGROUND TO THE INVESTIGATION

The investigation of likely environmental impacts of proposed hydro-electric schemes on the Zambezi River has come about due essentially to the concern of the Government conservation agencies and the general public for the wildlife of the Mana Pools National Park.

The Government ministry that has been centrally involved in the issue, from the conservation point of view, is the old Ministry of Natural Resources and Water Development, which became the Ministry of Natural Resources and Tourism in February, 1982. This ministry was divided into the Department of National Parks and Wildlife Management and the Forestry Commission (parastatal). The ministry has now lost the Division of Water Development and acquired the Department of Tourism. Closely associated with the Department of Natural Resources is the Natural Resources Board (NRB), which is a body of twelve people nominated by various organizations and appointed by the President. Among the interests that are represented on the NRB are commerce, mining and commercial and peasant farming. The NRB is an advisory body that considers Zimbabwe's current conservation issues, and is assisted in its deliberations by experts from various organizations both within and outside Government (including the University of Zimbabwe).

In 1970 the NRB set up the Zambezi Ecological Committee (which included both engineers and ecologists) to consider the downstream effects of floodgate discharges from Kariba Dam, particularly in relation to the Mana Pools "floodplains". The Chief Research Officer of the Department of National Parks and Wildlife Management, Dr. R.I.G. Attwell, had voiced concern over impoverishment of this habitat due to the Kariba scheme's interference with the natural flood regime of the Zambezi River. After meeting several times during 1970, the Committee decided that the problem of riverbank erosion at Mana Pools was "relatively insignificant in relation to the more serious ecological changes in the area"; these changes were outlined by Attwell (1970). The Committee recommended that the Central African Power Corporation (CAPCO)

take note of downstream ecological requirements in its operation of the Kariba floodgates, and that the Department of National Parks and Wildlife Management increase its research efforts in the Mana Pools area so it would be able to take appropriate action to minimise environmental degradation. The Committee was then temporarily disbanded.

In 1972, engineering consultants to CAPCO produced a report on possible new sources of power in Rhodesia; this report included feasibility studies of hydro-electric schemes at Mupata Gorge and Batoka Gorge, as well as at Victoria Falls and Devils Gorge. The power engineers saw the Mupata scheme in particular as being a necessary development once the country attained political and economic stability, and as the threat posed to the Mana Pools National Park by this scheme became public knowledge the inevitable storm of protest began to build up. In 1979, the NRB formed the Mupata Gorge Scheme Ecological Committee (essentially the old Zambezi Ecological Committee) to consider the problem. A Research Officer of the Department of National Parks and Wildlife Management, Mr. D.A. Peddie, was tasked with the compilation of relevant information on the scheme and the environment to be affected, and in 1980 the Committee produced a short "Preliminary Impact Statement" based largely on Peddie's information. This report has been criticized for containing an excessive amount of out-dated engineering information and very little ecological information, but it served to emphasize the fact that a thorough Environmental Impact Assessment of the Mupata scheme and its alternatives was required.

The need for such a study was endorsed by the Wildlife Society, which set up the Zambezi Valley Conservation Fund. The Department of National Parks and Wildlife Management stated that it was adamantly opposed to the construction of the Mupata scheme until all the environmental implications had been evaluated, and the Interpretive Officer of that Department, Mr. A.A. Ferrar, vigorously promoted this attitude through publications and talks which served to provide the public with more factual information. The Department of Land Management at the University of Zimbabwe developed an interest in the

issue during 1980 and its Professor, M.J. Blackie, produced several proposals for computer-based systems analyses and cost-benefit analyses of the Mupata scheme, assuming that considerable information was readily available.

The Director of Natural Resources, Mr. D.E. Lovemore, acted on an offer by Blackie to recruit two researchers for further investigations, and to provide facilities for them at the University, by securing a sum of $20 000 from the Zimbabwean Treasury to meet project expenses and the salaries of these researchers for a year. In February, 1981, Mr. M.J. Stanning and the compiler of this report were accordingly appointed to undertake, respectively, a Social Cost-Benefit Analysis and an Environmental Impact Assessment of the Mupata scheme and its most likely alternative on the Zambezi, the Batoka scheme. The information that was obtained was to be passed to the Mupata Gorge Scheme Ecological Committee. During 1981, this committee changed its name to the Committee to Advise on the Environmental Impact of Major Projects (CAMP) and acquired definite terms of reference. Rhodesian legislation had empowered the NRB to delay or prevent the construction of a dam or "conservation work" costing in excess of one hundred thousand dollars if this work was expected to cause major damage to the environment. In early 1981, this legislation was amended by the Zimbabwean Parliament since it was seen as being potentially obstructive to development and now the NRB is merely required to make reports on such projects to the Minister of Natural Resources and Tourism. The information gathered for CAMP is expected to serve as a basis for such a report on the Zambezi's hydro-electric schemes.

During 1981, work on the Environment Impact Assessment was carried out according to the modus operandi outlined in 1.5 and CAMP held several meetings to discuss progress. It was felt that the investigation would benefit from the advice of outside consultants so the International Union for Conservation of Nature and Natural Resources (IUCN) was asked to assist. The Swedish International Development Authority provided financial support for a mission from IUCN's Conservation for Development Centre (CDC). This mission consisted of the CDC Director, Mr. M.J. Cockerell, and a consultant

ecologist from East Anglia University, Dr. J.P. Barkham. These gentlemen visited Zimbabwe in September, 1981, and made recommendations on the methodology of the investigation. Barkham made another trip to Zimbabwe in December, and Cockerell is expected to return briefly when the final report on the hydro-electric schemes is synthesized by CAMP from this report and Stanning's report (around mid-April, 1982).

1.2 ZIMBABWE'S POWER SITUATION

(Information derived largely from Merz and McLellan, 1981)

Zimbabwe requires more power for industrial growth. At present, the annual requirement of electricity is almost 8 000 GWh, of which about 30 per cent is imported from Zambia, and this requirement is expected to increase at a rate of 5 to 8 per cent each year. A country must maintain a reserve margin of generating capacity in order to cover planned maintenance of plant and forced outages; for Zimbabwe, the reserve margin is recommended to be about 20 per cent of total installed capacity. The inadequate reserve margin that Zimbabwe suffers at present will be corrected when a 480 MW thermal station presently under construction (Wankie 1) is commissioned during 1983, but, with the increasing electricity demand and the loss of output from obsolete thermal stations, Zimbabwe will again have an inadequate reserve margin by 1986 unless additional plant is installed.

In early 1981, Merz and McLellan, in association with Sir Alexander Gibb and Partners and Coopers and Lybrand Associates Limited, were engaged to determine the cheapest generation and transmission solution to meet Zimbabwe's expected demands for power. At this stage, a hydro-electric scheme at Mupata Gorge was thought by many to be an attractive option for the near future. The power consultants concentrated on the possibilities of hydro-electric schemes on the Zambezi, thermal power stations, and further imports of electricity from neighbouring countries. Solar, wind and small-scale power sources were discounted as being inadequate for industrial requirements.

As regards importation of electricity, it is estimated that

Zambia's installed generating capacity will be more than sufficient for Zambian electricity demands until the mid-1990's, so until then a surplus will be available for Zimbabwe. There is also a surplus of electricity in Zaire; the completed Inga II hydro-electric scheme on the Zaire River has an installed capacity of 1 280 MW which is yet to be utilized. In Mocambique, the south bank of Cabora Bassa has an installed capacity of 2 075 MW and it would be possible to install additional plant up to about 600 MW on the undeveloped north bank. Mocambique has a legal obligation to supply South Africa with electricity from the south bank station, although South Africa is presently unable to rely on this source of electricity due to sabotage of the transmission lines in Mocambique by anti-Frelimo guerrillas. The surplus capacity for firm output at the south bank of Cabora Bassa is about 120 MW, and it would be possible to make a 220 kV link to Umtali by reinforcing existing lines so that this capacity could be utilized by Zimbabwe. Since the Zimbabwean transmission system is 330 kV, Umtali and adjacent areas would have to be split from the national grid and supplied entirely from Mocambique.

The expansion of the Cabora Bassa plant would be relatively cheap, and if funding were available Mocambique could have 600-800 MW for Zimbabwe's use within the next ten years, in addition to what might be derived from Zambia and Zaire. A merit of importing is that it requires a much smaller capital investment than additional internal plant. However, the power consultants concluded that electricity imports should not exceed about 15 per cent of Zimbabwe's maximum demand (a country's reserve capacity should ideally be greater than its imports). It seems that the politicians' argument that it would be strategically unwise for Zimbabwe to rely on power sources in other countries will prevail over the conservationists' argument that the existing sources of power in Central Africa should be used more economically.

Zimbabwe has vast coalfields; the country's coal reserves (to a depth of 200 metres) are estimated to be in the order of 30 000 million tonnes, which comprise about 0,5 per cent of

the world's total reserves. Wankie is the only producing colliery at present. As mentioned, the Wankie I power station (480 MW) is nearing completion. The Electricity Supply Commission had received very favourable tenders for additional plant at Wankie (Wankie II) which were a reflection of the poor demand for thermal power plant in other parts of the world. Every year, some 2,5 million tonnes of low-grade coal are stripped off underlying coking coal at the Wankie opencast workings and are pushed aside to combust spontaneously. This wastage could be corrected by using the low-grade coal to raise steam for the turbines not only of Wankie I but also of an additional power station. However, the Government delayed its decision on whether or not to proceed with Wankie II until the power consultants produced their report. The possibility of building a thermal power station on another coalfield, such as that at Sengwa, had to be considered too.

Large amounts of electricity could be generated by several hydro-electric schemes on the Zambezi, in addition to Cabora Bassa, Kariba and the small Zambian power station at Victoria Falls. Such schemes would come under the direct control of the Central African Power Corporation (CAPCO), which operates in conjunction with the Zimbabwean Electricity Supply Commission and the Zambian Electricity Supply Corporation.

Zimbabwe could increase its ability to meet peak electricity demands most cheaply by installing two new 150 MW sets on Kariba's south bank, thus bringing the total installed capacity of Kariba up to 1 566 MW. The exploratory drilling work has already been completed, and the new sets could be commissioned within four years after the award of contracts. Two more sets could also be installed on the north bank of Kariba (making Kariba's total capacity 1 866 MW). The Zambian authorities have not yet agreed to the extension on the south bank (their co-operation is required since Zambia is entitled to half the hydro-electric potential of the Zambezi along its border); for various reasons, they would rather have the north bank station extended first, although their country does not need more power for many years. In due course, however, the

international agreement to proceed with the south bank extension is likely to be forthcoming.

Apart from the Kariba extensions, the other hydro-electric options are new stations at Victoria Falls, Batoka Gorge, Devils Gorge and Mupata Gorge. The Victoria Falls scheme is not likely to eventuate for many years since its installed capacity would probably be less than 300 MW and its output would fluctuate considerably due to seasonal variations in river flow. An installed capacity of 500 MW might be possible in conjunction with a storage reservoir at Katombora (about 65 kilometres upstream of the Victoria Falls). This reservoir could be used to regulate the river flow so that the discharges over the Falls could be increased at times of low natural flow and reduced at times of high natural flow. However, the extensive, shallow reservoir would flood large parts of adjacent countries, with only a small area affected in Zimbabwe, and would reduce the annual Zambezi flow by about 7 per cent due to evaporation (Ministry of Lands, 1972). In view of the uncertainty of reaching international agreement on the Katombora reservoir, it is not regarded as a likely proposition.

The Devils Gorge scheme has also been given less attention than the other options. This scheme would involve the construction of a double curvature concrete arch dam (maximum height 181 metres) at a site about 2 kilometres downstream of the Gwaai/Zambezi confluence. It would have an installed capacity of about 1 600 MW. The capital cost would be well over Z$1 000 million (at current prices) and the 100 kilometre-long reservoir would flood a very large area.

The Batoka scheme (1 600 MW) and the Mupata scheme (1 200 MW) have emerged as the most attractive hydro-electric options after the Kariba extensions. These schemes are discussed in more detail in 1.4. Exploratory drilling has commenced at both sites. Initially, the geological formations at Batoka Gorge were thought to be less favourable for dam construction than those at Mupata Gorge. Although it is still too early to make an accurate assessment, preliminary indications are that this may not be the case. The Batoka scheme would produce

more electricity than would the Mupata scheme so although its capital cost would be greater (in the order of Z$1 000 million as opposed to about Z$900 million, at current prices) the cost per kilowatt of electricity from this scheme would be less than that of the electricity from the Mupata scheme.

Towards the end of 1981, Merz and McLellan and their associates produced their final report. This outlined various possible programmes for new plant which were based on different assumptions regarding firstly, growth in electricity demand, and secondly, the extent of Zambian agreement to Zambezi hydro-electric schemes. Environmental costs were not considered.

Although the Kariba extensions (both north and south bank) would be the cheapest means of providing electricity to meet peak demands, they could not be completed in time to solve Zimbabwe's likely power shortage in 1985. The only scheme that could be completed in time is Wankie II with two 200 MW sets. Thus the consultants recommended that Zimbabwe should start first with Wankie II and then bring the Kariba south bank extensions into operation, followed by the north bank extensions (assuming Zambian co-operation). The Batoka scheme would be the next most economical option, but it could not be introduced in time to meet the electricity shortfall that would occur (even with the additional 480 MW plus 400 MW of Wankie I and II and 300 MW plus 300 MW at Kariba) towards the end of the decade. Thus further sets would have to be commissioned at Wankie, followed then by the Batoka scheme and the Mupata scheme. These developments would satisfy the joint requirements of Zimbabwe and Zambia until 2000. Obviously, a different programme, with greater emphasis on thermal power stations, would be required if Zambia did not wish to co-operate in joint hydro-electric schemes.

The Zimbabwean Government concurred with the findings of the consultants and secured funding for the two additional generating sets to be installed at Wankie. Negotiations with Zambia over the proposed Kariba extensions are continuing. It should be mentioned that the advantage of the hydro-electric extensions at Kariba is not that this plant would provide additional firm output but that the turbines could

be started up quickly when required to meet peak electricity demands. With Wankie I, and with another two steam turbines at Wankie and the Kariba extensions, Zimbabwe would have a sound generating system since the thermal power stations (which are not suited to variable output) could be used to meet most of the base load and the full hydro-electric generating capacity could be used for "peaking".

1.3 GENERAL GEOGRAPHY OF THE AREAS OF CONCERN

The Mupata Gorge hydro-electric scheme would flood a portion of the Zambezi Valley downstream of Kariba, while the Batoka Gorge hydro-electric scheme would flood a portion of the deeply-incised section of the Zambezi River downstream of the Victoria Falls. The Zambezi Valley, within Zimbabwe, is often referred to simply as "the Valley" and this terminology is used in this report, while the Batoka Gorge is referred to as "the Gorge".

The Valley, for the purposes of this study, may be said to lie approximately between longitudes 28° 50' E and 30° 10' E, and latitudes 15° 37' S and 16° 22' S. It is bounded to the west by Kariba Gorge, and to the east by Mupata Gorge, to the north by the Zambezi River (the Zimbabwean side only is considered) and to the south by the Zambezi Escarpment. The Escarpment is the northern edge of the Central Zimbabwean Plateau, and the Vadoma Hills on the north-east margin of the Valley, south of Mupata Gorge, are a southerly extension of the Zambian Plateau. The Valley is a down-faulted trough with the main fault-line running along the base of the Escarpment. The floor of the Valley varies in altitude from 350 m to 640 m above sea-level, being somewhat undulating despite its deceptively flat appearance from the air, and the Escarpment rises up to 1 200 m above sea-level. The main rivers draining into the Zambezi from the Zimbabwean side are the Nyakasanga, the Rukomechi, the Chiruwe, the Sapi, the Chewore and the Mwanja. A large portion of the Zambezi National Parks and Wildlife Estate falls within the Valley: this estate includes:

Urungwe Safari Area	2 878 km^2
Mana Pools National Park	2 196 km^2

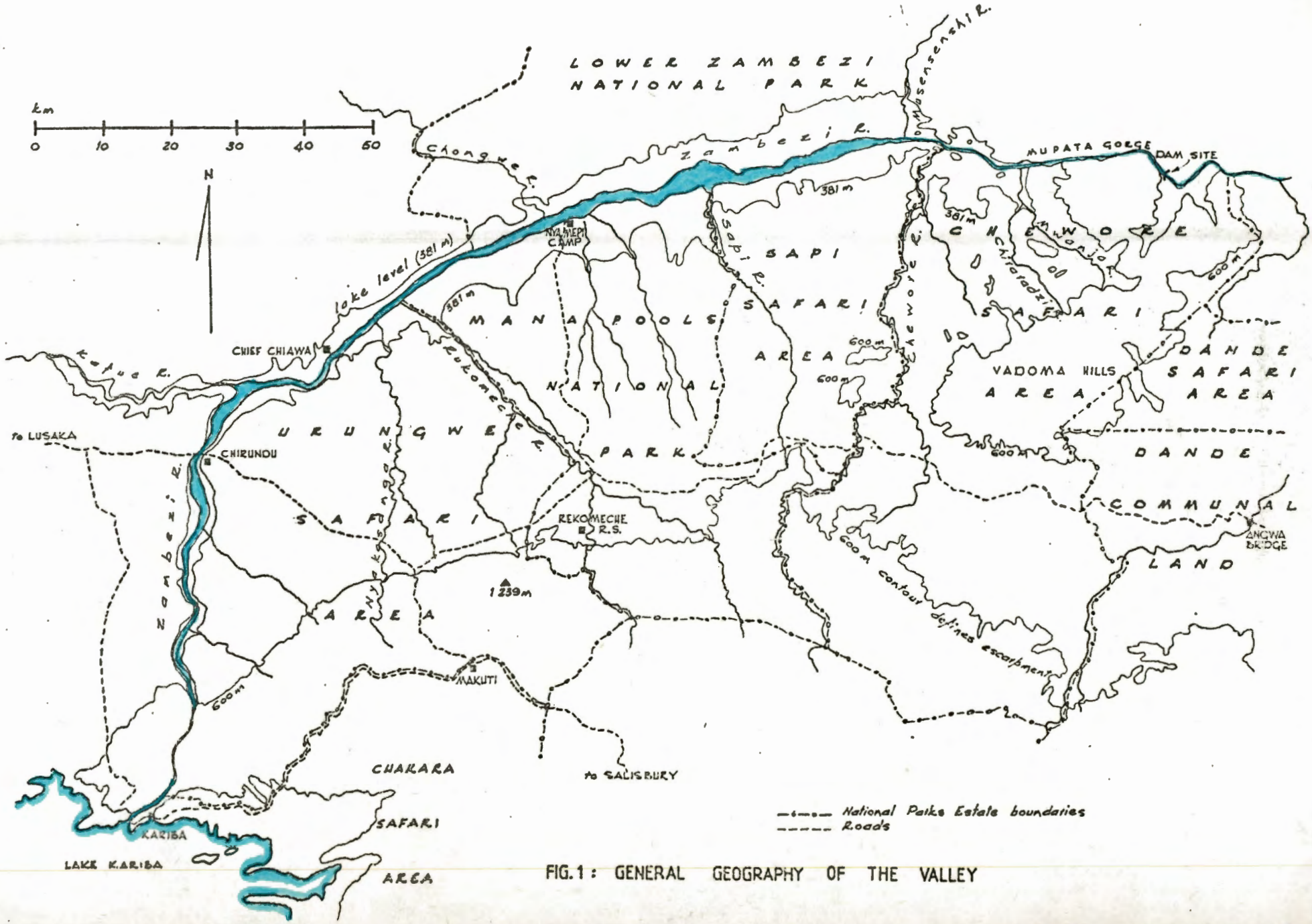


FIG. 1 : GENERAL GEOGRAPHY OF THE VALLEY

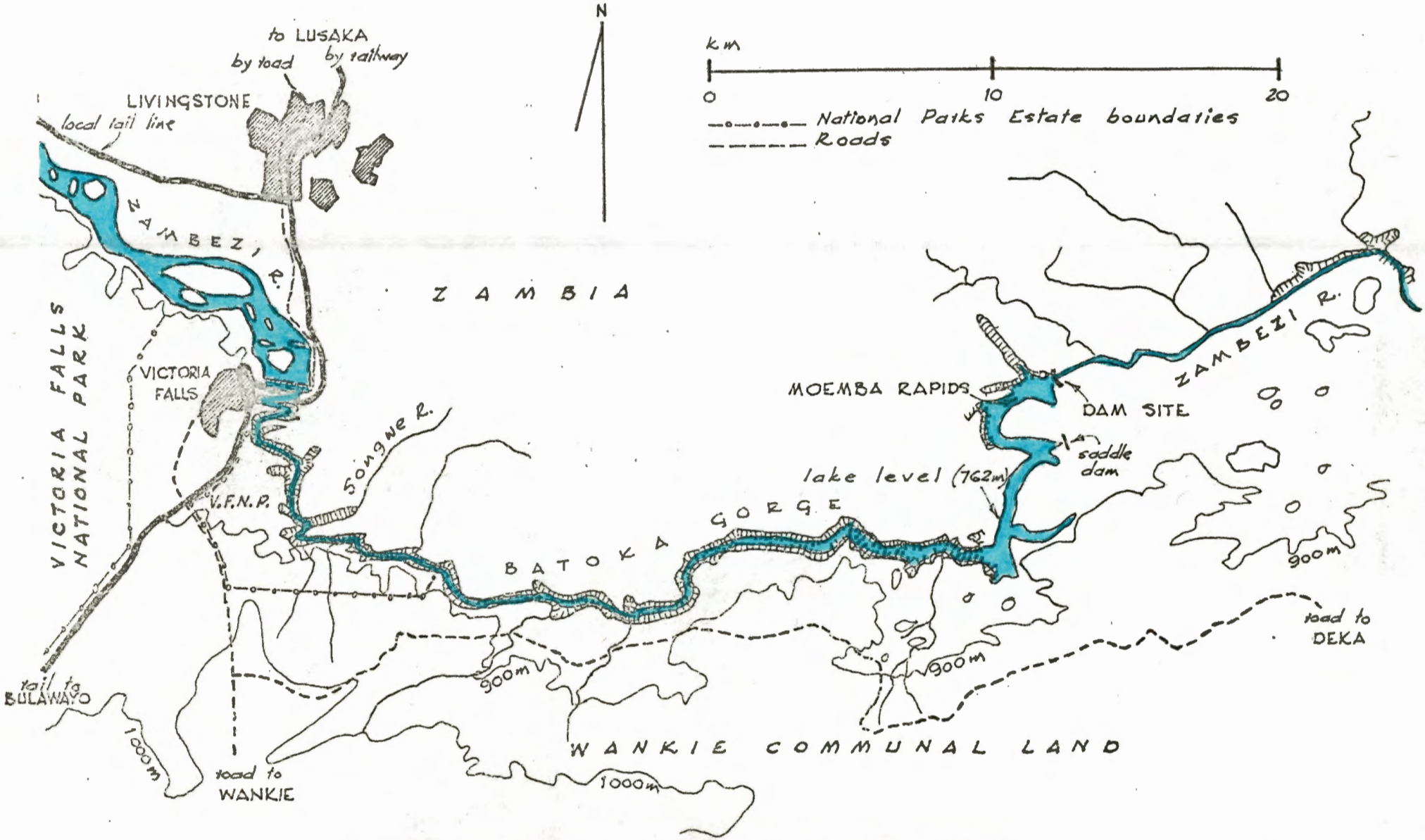


FIG. 2 : GENERAL GEOGRAPHY OF THE GORGE

Sapi Safari Area 1 180 km^2
Chewore Safari Area 3 390 km^2

(These figures represent the total extents of the wildlife areas and not just the portions that fall within the Valley).

The Batoka Gorge winds for 90-100 km below the Victoria Falls (25° 51' E - 26° 35' E ; 17° 51' S - 18° 0' S). Over this distance, the basalt rock through which the narrow defile has been cut remains more or less horizontal (about 800 m above sea-level), but the Zambezi River drops approximately 260 m from its level at the base of the Falls. Thus the Gorge deepens progressively; it is about 110 m deep at the Falls themselves but at its downstream end it approaches a depth of 350 m, although the walls here are less precipitous (Phillipson, 1975). There are no major waterfalls on the Zambezi within the Gorge and thus most of the drop of the river is accounted for by a series of rapids, of which the Chimamba Rapids (Moemba Falls), some 36 km east of the Victoria Falls, are the most impressive. Seasonally-flowing tributaries enter the Gorge as scenic waterfalls. On the Zimbabwean side, a small section at the upper end of the Gorge consists of National Parks estate and the rest of the Gorge is bordered by the Wankie communal lands, although no tribespeople live close to the Gorge because of the broken nature of the terrain here. There is presently a severe restriction on movement in the area adjacent to the Gorge due to the presence of anti-personnel mines that were laid during the recent war.

1.4 DETAILS OF PROPOSED HYDRO-ELECTRIC SCHEMES

(Information derived largely from Merz and McLellan, 1981)

1.4.1 The Mupata Scheme

Available topographical survey information is insufficiently detailed to permit the engineers to make a precise choice of the retention level of the reservoir; its normal operating level has been provisionally set at 381 m above sea-level. A higher level would necessitate substantial modification of Chirundu Bridge, which would not be worthwhile because the lake-level could be raised only slightly more before Lake Mupata's headwaters interfered with the tailraces at Kariba. The site for the wall has been chosen as far downstream in

Mupata Gorge as possible without introducing the need for saddle dams to prevent the reservoir from overflowing into the basin of the Luangwa River. The scheme would be operated in a run-of-river mode, with the inflow regulated as much as possible by the Kariba and Kafue schemes. The fact that the inflow could be regulated so that the lake-level is kept fairly constant is important since, with the operating head in the range 50-55 m, a drop in head of even 5 m would have a significant effect on power output. About $7,4 \times 10^9$ m^3 of live storage could be used, with a minimum retention level of 375 m above sea-level, to provide additional regulation of flow past the turbines, but this is unlikely to result in any significant increase in firm energy output since it would involve the loss of valuable head.

The lake would be narrow, with 54 per cent of its area in Zimbabwe and 46 per cent in Zambia, and shallow (70 per cent of its volume would be in the top 16 m). The alluvial area at Mana Pools would be permanently inundated. A low-level scheme, which would avoid flooding this sensitive area, has been considered; the lake would then have a level of 354 m above sea-level in the dry season, rising to 359 m in the wet season, when the alluvial area would be flooded. It is thought that such a scheme would "simulate the historic regime of annual inundation in the area and so encourage the continuance of prevailing habitats and animal life" (Merz and McLellan, 1981, Vol. 2, 5.12). However, the Mupata low-level scheme would be very uneconomic, relative to other power schemes that are possible in Zimbabwe.

It would be necessary to provide access to the dam site on both sides of the river and, in view of the rugged nature of the terrain and the absence of roads, this would constitute a significant proportion of the total cost of the scheme. On the south side, over 30 km would have to be traversed downstream of the dam site before reaching the existing secondary road to Kanyemba. During the exploratory drilling operations, equipment and personnel are conveyed by barge from Kanyemba. The nearest Zimbabwean railhead would be at Lions Den, about 300 km away.

1.4.2 The Batoka Scheme

Again, the area has not been accurately surveyed and, in fact, the site for the proposed dam had to be moved about 10 km upstream from the point that was chosen in 1972, since a major error was discovered in the cartography. The dam has to be sited so that Lake Batoka would not affect the operation of the Zambian power station at Victoria Falls, and so that the proposed Devils Gorge scheme downstream could later be developed to its full potential. The provisional normal retention level is 762 m above sea-level. The scheme would be operated in a run-of-river mode and, since there would be no regulation of the inflow (unless the Katombora barrage is constructed) the lake-level would fluctuate far more during the year than would Lake Mupata's level (i.e. possibly 8 m or more). The lake would be confined within the Gorge, and would be deep, narrow and winding. A 5 m high saddle dam would be required on the south bank, about 3 km from the main dam, in order to prevent the water from spilling down a fault line.

The terrain around Batoka Gorge is very broken so road access on both sides would be difficult and costly. A road sufficient to meet the requirements of the team that is doing the exploratory drilling was constructed on the south side during 1981. The nearest railheads are at Matetsi (50 km) and at Livingstone (40 km).

TABLE 1

DETAILS OF ZAMBEZI HYDRO-ELECTRICAL SCHEMES

(Merz and McLellan, 1981; Olivier, 1975; Bond and Roberts, 1978)

	MUPATA	BATOKA	KARIBA	CABORA BASSA
Geographical position of the lake Longitude Latitude	 28°38'E-30°12'E 15°34'S-16°23'S	 20°51'E-26°07'E 17°56'S-18°00'S	 26°40'E-29°03'E 16°28'S-18°06'S	 30°25'E-32°44'E 16°29'S-16°00'S
Main axis of lake	WSW-ENE	W-E	SW-NE	W-E
Approximate length of lake (km)	200	50	300	250
Greatest width of lake (km)	14	2	40	38
Normal area of lake (km^2)	1 230	20	5 250	2 740
Mean depth of lake (m)	16	70?	29	26
Normal volume of lake (10^9 m^3)	19,8	2,0	156,5	70,0
Filling time	1 year	1 month	4 years	1 year
Grid reference of wall	ST 991676	ML 056179	PM 881728	?
Type of wall	Concrete gravity?	Double curvature concrete arch	Double curvature concrete arch	Double curvature concrete arch
Maximum height of wall (m)	78	196	128	176
Maximum floodgate discharge (m^3 sec^{-1})	14 400	17 000	9 500	13 200
Installed capacity (MW)	1 200	1 600	1 266	2 075
Possible firm output (GWh yr^{-1})	6 100	9 200	9 700	?
Firm output of scheme + Kariba with 600 MW extensions (GWh yr^{-1})	15 800	18 900	-	-

1.5 METHODOLOGY

When the investigation commenced in February, 1981, it was understood that the Zimbabwean Government wished to make a final decision within a year on whether or not to proceed with the Mupata scheme. Accordingly, the somewhat ambitious objective that was set for the investigation was the production of an Environmental Impact Statement that contained not only such information on likely impacts as could be gathered within a short time but also an evaluation of the predicted impacts. Final Environmental Impact Statements are inadequate if they merely outline a set of likely impacts without providing some perspective for the decision-makers on the actual significance of each impact in terms of the overall project and environment. Since there was no precedent for this type of investigation in Zimbabwe, it was necessary to review a range of methods of Environmental Impact Assessment (du Toit, 1981). The idea of a Cost-Benefit Analysis was already firmly entrenched in the minds of those who were centrally involved in the initiation of the investigation, so an approach was devised that incorporated this technique, in addition to the use of a matrix technique, summary sheets and a psychometric scaling technique that is not known to have been used in Environmental Impact Assessment before (du Toit and Stanning, 1981).

As regards the collection of data on the environments of the Gorge and the Valley, it was felt that much reliance could be placed on local expertise since there is a particularly good spirit of co-operation among the scientific community in Zimbabwe, and the widespread interest in the "Mana Pools issue" meant that scientists would be fairly willing to become involved in the investigation, without financial inducement. Subsequent experience has shown that this belief was correct. Scientists from the University of Zimbabwe and from Government agencies attended a workshop at which a list of relevant environmental components was produced, and names were suggested of experts who might be available to provide information on each component. These experts were then approached, and without exception they agreed to assist or else suggested others who would be in a better position to provide information.

Details of the hydro-electric schemes were given to the consultant scientists. Over the next ten months or so, reports on the individual environmental components and the likely effects of the hydro-electric schemes were given by the consultants, either verbally or in writing, to the compiler. Another workshop was held in December, 1981, to discuss findings.

As the investigation proceeded, it became evident that the time constraint and lack of resources would preclude the production of the desired Final Environmental Impact Statement. However, this was not seen as a cause for alarm because the study that was being undertaken concurrently by the power consultants indicated that neither the Mupata scheme nor the Batoka scheme would be started as soon as originally thought. It was therefore accepted that a Preliminary Environmental Impact Statement would be produced, as a foundation for future elaboration, without an attempt at evaluating the impacts apart from the Cost-Benefit Analysis, which became something of a separate exercise anyway. The Cost-Benefit Analysis (Stanning, in preparation) must be seen as a tentative attempt at quantifying some of the socio-economic aspects of the proposed schemes; lack of data and lack of precedent for this type of work in Zimbabwe mean that this economic analysis is somewhat exploratory in nature. The ways in which the Preliminary Environmental Impact Assessment might be elaborated on are discussed in 4.

1.6 CONSULTANTS

The following persons gave advice on particular aspects during the investigation, and some produced written contributions. A file containing the original reports is held in the library of the Department of National Parks and Wildlife Management, Salisbury, Zimbabwe.

Climate

J.D. Torrance, MLM, BSc (Dept. of Meteorological Services, Zimbabwe).

Geology and Geomorphology

C.B. Anderson, BSc (Dept. of Geological Survey, Zimbabwe) : economic geology.

H.C.P. Nugent, BSc (Dept. of Geology, University of Zimbabwe) : geomorphology.

J.L. Orpen, DPhil (Dept. of Geology, University of Zimbabwe) : general geology.

J.D. Torrance (as above) and J.N.F. Allen (Goetz Observatory, Bulawayo) : seismic effects.

Vegetation

Th. Muller, BSc, and G.V. Pope, MPhil (National Herbarium, Zimbabwe).

Terrestrial Invertebrates

R.J. Phelps, PhD (Dept. of Zoology, University of Zimbabwe)

Amphibians and Reptiles

D. Blake (Dept. of National Parks and Wildlife Management, Zimbabwe).

Ornithology

A.J. Tree, BSc, Grad CE (President of the Ornithological Association of Zimbabwe).

Mammals

J.B. Condy, FRCVS, Dr Med Vet, DTVM (Dept. of Veterinary Services, Zimbabwe) : animal diseases.

K.M. Dunham, MPhil (Dept. of National Parks and Wildlife Management, Zimbabwe) : primary productivity.

R.D. Taylor, MSc (Dept. of National Parks and Wildlife Management, Zimbabwe).

Limnology

P. Fair, PhD (Dept. of Botany, University of Zimbabwe) and C.H.D. Magadza, PhD (Dept. of Zoology, University of Zimbabwe).

B.E. Marshall, MPhil (Lake Kariba Fisheries Research Institute).

Aquatic Vegetation

P. Fair, C.H.D. Magadza and B.E. Marshall (as above).

Icthyology

B.E. Marshall (as above).

Human Health

H.V. de V. Clarke, PhD, and
R.J. Phelps, PhD (Dept. of Zoology, University of Zimbabwe).

D.F. Lovemore, OLM, MSc (Director, Dept. of Natural Resources, Zimbabwe) : trypanosomiasis.

M.H. Webster, ICD, OBE, BL, MBChB, DPH, FFCM (RCP), FRSH (Dept. of Law, University of Zimbabwe).

Ethnography

S.T. Nduku, BA (Queen Victoria Museum, Salisbury) : shrines.

Safari Hunting

V.R. Booth, MSc (Dept. of National Parks and Wildlife Management, Zimbabwe).

M.J. Stanning, MSc (Dept. of Land Management, University of Zimbabwe).

Conservation

C.A.M. Attwell, PhD (Division of Biological Sciences, University of Zimbabwe) : genetic conservation.

D.H.M. Cumming, PhD (Dept. of National Parks and Wildlife Management, Zimbabwe) : conservation of *Acacia* riparian woodlands).

Th. Muller, and
G.V. Pope (as above)

General

J.P. Barkham, PhD (Consultant ecologist, International Union for Conservation of Nature and Natural Resources).

M.J. Cockerell, CEng, MIMechE, MIA (Director, Conservation for Development Centre, International Union for Conservation of Nature and Natural Resources).

R.F. Fuggle, PhD (Director, School of Environmental Studies, University of Cape Town).

2. THE MUPATA SCHEME

2.1 CLIMATE

2.1.1 Current Climatic Conditions in the Valley

In an outline of climatic comfort zones, the Valley downstream of Chirundu is classified as "excessively hot" (Dept. of Meteorological Services, 1981). This area is the only part of Zimbabwe to fall into this category.

Extensive meteorological observations have been made only at Chirundu (about 1,5 km from the Zambezi River) and at the Rukomechi Research Station (on the Rukomechi River near the base of the Escarpment). These data show that the rainfall is usually confined to the period from November to March. A figure for the mean annual rainfall of the Valley is difficult to establish. The mean annual rainfall for Chirundu, averaged over 30 years, is 628 mm . Rainfall data from Mana Pools, kept since 1967 (Table 4), show that the mean annual rainfall for this locality is 838,2 mm; these data also indicate that the annual rainfall is highly variable.

A cool, dry season lasts from May to August, followed by increasingly hot, dry weather until the rains break. The coolest month is July, when the daily maximum temperatures are around 28° C, and the hottest month is October, when the daily maximum temperatures are usually around 37° C. Between October and the rains, maximum temperatures may sometimes be several degrees above 40° C.

At Chirundu, north-easterly winds prevail in all months of the year, being funnelled between the Zambian and Zimbabwean escarpments, about 25 km to the north-west and south-east respectively. Wind speeds are low at night but increase soon after sunrise, and reach their maximum at about midday. September-October is usually the windiest period, with average midday winds of about 12 knots. Gusty conditions are fairly common at Chirundu, with over 100 days during the year when gusts reach or exceed 25 knots. During the rainy season, gusts of 45 knots or more may occur.

TABLE 2

CLIMATOLOGICAL DATA FROM CHIRUNDU SUGAR ESTATE

LOCATION 16° 00'S 28° 54'E ALTITUDE 392 m PERIOD February, 1957 - June, 1967

	Mean Daily Maximum Temp.(°C)	Mean Highest Maximum Temp.(°C)	Absolute Maximum Temp.(°C)	Mean Daily Minimum Temp.(°C)	Mean Lowest Minimum Temp.(°C)	Absolute Minimum Temp.(°C)	24 - hour Mean Temp. (°C)	24 - hour Mean Rel.Humidity (%)	Daily Sunshine (hours)	Evaporation (mm)	Rainfall (mm)	Mean Wind Direction(degrees)	Mean Wind Speed (knots)
JUL	27,8	30,9	32,8	10,3	6,5	2,3	19,1	56	8,7	135	∅	054	3,9
AUG	30,5	34,9	36,6	12,5	8,3	6,6	21,6	48	9,4	182	∅	059	5,0
SEP	33,9	38,3	39,8	17,3	12,0	7,6	26,0	41	9,1	240	∅	063	6,4
OCT	36,6	40,9	41,7	21,2	15,7	13,1	29,3	37	9,1	285	9	065	6,2
NOV	35,3	40,1	42,8	22,7	19,2	16,7	28,7	52	7,3	217	58	063	4,6
DEC	32,2	38,2	40,8	21,9	19,3	17,1	26,5	71	5,7	151	155	063	3,0
JAN	31,1	35,3	38,4	21,5	19,6	17,2	25,6	79	5,9	147	169	059	5,0
FEB	30,7	34,5	37,3	21,5	19,7	18,2	25,3	81	5,6	126	144	059	2,3
MAR	31,3	34,6	36,3	20,1	16,8	15,1	25,2	75	8,3	149	71	061	2,9
APR	31,6	35,2	36,3	18,0	13,6	11,1	24,3	67	8,7	135	20	056	3,4
MAY	29,9	34,0	36,6	13,5	8,3	6,5	21,3	63	9,2	124	1	055	3,3
JUN	28,0	31,6	34,1	10,8	7,0	5,1	19,1	61	8,6	107	1	059	3,4
YEAR	31,6	35,7	42,8	17,6	13,8	2,3	24,3	61	8,0	167	628		

The symbol ∅ has been used to indicate a value which is greater than 0 but not as much as 0,5.

TABLE 3

CLIMATOLOGICAL DATA FROM RUKOMECHI RESEARCH STATION

LOCATION 16° 08' S 29° 24' E ALTITUDE 504 m PERIOD November,1959 - June,1976

	Mean Daily Maximum Temp.(°C)	Mean Highest Maximum Temp.(°C)	Absolute Maximum Temp.(°C)	Mean Daily Minimum Temp.(°C)	Mean Lowest Minimum Temp.(°C)	Absolute Minimum Temp.(°C)	Relative Humidity at 0730 hrs (%)	Rainfall (mm)
JUL	27,4	31,1	33,1	13,1	9,4	7,2	66	0
AUG	30,1	34,6	35,6	14,8	10,3	3,9	57	1
SEP	33,5	38,0	39,5	18,6	13,2	9,4	48	1
OCT	36,2	40,7	42,2	22,6	17,6	15,0	45	7
NOV	34,8	40,7	43,5	22,8	18,7	15,0	56	59
DEC	32,7	38,3	43,0	21,9	19,2	17,2	76	214
JAN	31,9	35,7	40,0	21,4	18,9	15,0	83	177
FEB	31,6	35,4	38,0	21,2	18,9	13,3	82	125
MAR	31,8	35,3	38,9	20,8	17,9	12,2	77	84
APR	31,1	34,8	37,8	19,5	15,5	13,3	72	19
MAY	29,5	33,8	36,1	16,2	11,7	8,3	68	3
JUN	27,4	31.1	33,6	13,5	9,6	2,2	68	Ø
YEAR	31,5	35,8	43,5	18,9	15,1	2,2	66	690

The symbol Ø has been used to indicate a value which is greater than 0 but not as much as 0,5.

TABLE 4

RAINFALL RECORDS FROM NYAMEPI CAMP, MANA POOLS NATIONAL PARK.

TOTAL ANNUAL RAINFALL

Years	mm
67/68	504
68/69	928
69/70	932
70/71	704
71/72	814
72/73	405
73/74	No record
74/75	No record
75/76	1134
76/77	606
77/78	1538
78/79	580
79/80	771
80/81	999

MEAN MONTHLY RAINFALL

Month	mm
July	0
August	0,1
September	0
October	17,1
November	79,4
December	247,7
January	169,8
February	155,9
March	118,0
April	45,1
May	4,5
June	0

MEAN ANNUAL RAINFALL : 383,2 mm.

2.1.2 Climatic Effects of Lake Mupata

(Information derived from the contribution of Torrance, 1981)

"The changes outlined here will commence gradually and progressively as the lake fills, stabilising to the extent shown when the lake is at its normal retention level."

The Influence of Lake Mupata on Temperatures "Within 10 km of the lake, maximum temperatures will be about 2° C lower during the dry season, and about 1° C lower during the rainy season. Afternoon lake breezes may extend beyond 10 km , but are more likely to reduce the duration of higher afternoon temperatures than to cause a significant lowering of the maximum. Changes in minimum temperatures will be within 1° C for the most part, plus or minus. Present minimum temperatures at the tops of hills in the area to be inundated will possibly be reduced if these hills become islands; this would be microclimate effect."

The Influence of Lake Mupata on Humidity and Rainfall

"Within 10 km of the lake (and during occasions of steady wind as far as 50 km downwind of the lake), the relative humidity will be 5 per cent to 10 per cent higher. Rainfall over the lake area will increase from what it was over the dry valley, and rainfall over neighbouring escarpments should also increase. Little change is expected during the dry season. The Zambian escarpment should gain more than the Zimbabwean, due to closeness, steepness and wind directions that are more directly up-slope. However, when the general windflow becomes more northerly and north-westerly, as when a Zambian low-pressure area becomes established, or during generally falling pressure, the emphasis will move to the Zimbabwean side. Gains of over 30 per cent on mean annual rainfall have been verified in respect of Lake Kariba, and can be expected in this area also, petering out by 50 km from Lake Mupata."

"The diurnal variation of rainfall will change due to the presence of the lake. During the day, conditions over

the lake should be mainly clear, with most rainfall occurring at night and in the early morning, whereas storms will develop over neighbouring hills and escarpments by midday with peak activity in the afternoon and early evening."

The Influence of Lake Mupata on Winds "Chirundu wind records show winds from between north and east for over 90 per cent of the time, with peak speeds in the afternoon, and, as elsewhere, highest speeds in September-October. With Lake Mupata, afternoon winds at the western end may be a couple of knots stronger, on average. Land and lake breezes will occur, though not as strongly as at Lake Kariba. The directions expected for the afternoon lake breezes are south to south-east on the Zambian shore, and north-east on the Zimbabwean shore. These breezes should extend as far as the nearest escarpment. The occasional south-westerly gales, so severe on Lake Kariba, should be absent from Lake Mupata. Very sudden changes of wind direction and speed can be expected on the lake, especially in the middle reaches, mainly during the rainy season. These will originate in the squalls from thunderstorms over the neighbouring hills and escarpments, and additionally there should be down-slope (gravity) movement of air cooled by rain falling on slopes. Because of the proximity of the Zambian hills, they should generate most of these squalls, with wind directions from between north-east and north-west."

"Overall, this should be a windier lake than Lake Kariba, with winds mainly from between north-east and east, and with stronger winds from between east-north-east and east-south-east during periods of rising pressure. Thus most winds will blow up the lake, with greatest effect in raising waves. On average the winds will be strongest in October. Given a sustained wind of 20-25 knots blowing up the lake, the waves generated on the open stretch towards Chief Chiawa's village (map reference QN 2042) will have extreme values of 1,5 to 2,0 m from trough to crest. Because of the constriction and

change in orientation of the lake in the vicinity of this village, the waves at Chirundu Bridge should be much less than on the open lake to the east of the narrows. Extreme waves at Chirundu Bridge should be no more than 0,75 m to 1,0 m from trough to crest, or say 0,4 m to 0,5 m above undisturbed lake level."

See 2.9.2 for notes on the evaporation rate associated with Lake Mupata.

2.2 GEOLOGY AND GEOMORPHOLOGY

2.2.1 General Geology of the Valley

(Information derived largely from the contribution of Anderson, 1981)

Available information on the geology of the Valley comes from a few, mostly unpublished, accounts spread over decades and cannot be regarded as being sufficiently detailed for anything more than a provisional regional geological summary.

The oldest rocks in the area are those of the Precambrian Basement, forming the Escarpment and the mountains around the Kariba and Mupata gorges. These rocks are mainly metamorphosed and deformed gneisses and paragneisses. The mountains south of the Mupata Gorge contain a differentiated ultramafic intrusion near the mouth of the Mwanja River. This intrusion, possibly related to the Great Dyke in origin, forms on surface three roughly evenly-spaced outcrops totalling about 26 km^2 in area, aligned north-east/south-west and spread over a distance of 18 km. The exposures are almost certainly connected beneath intervening younger Karoo sediments. The total subsurface extent of the Chewore Igneous Complex, as these rocks are called, is unknown.

The remainder of the Valley is almost entirely underlain by Karoo rocks. These clastic sediments are interpreted as the products of fluviate and aeolian deposition between the Permian and the Jurassic (about 280 - 135 million B.P.). The sediments are faulted and tilted (Maufe, 1935) to give a gently-undulating topography. The basalts which cap the sedimentary succession in other parts of Zimbabwe are found only as a

FIG. 3

GEOLOGY OF THE VALLEY

small outlier downstream of Chirundu.

Post-Cretaceous sediments occur as alluvial beds along the flanks of the larger streams and rivers, and as outwash fans radiating from the Escarpment base near the Chewore River and further west between the Rukomechi River and the Kariba Gorge.

2.2.2 Erosion and Deposition along the Middle-Zambezi

(Information derived largely from the contribution of Nugent, 1981)

Along much of its course between the Kariba and Mupata gorges, the Zambezi flows over discontinuous tracts of its own alluvium, which appear to be confined within a belt about 5 - 10 km either side of the river.

Stocklmayer (1980) mapped the alluvium on the Zimbabwean side between Chirundu and the Chewore confluence from 1973 aerial photography. He considered the alluvium to slope towards the river in a series of terraces, each of these supporting a characteristic vegetation type. Table 5 summarizes his classification of the terraces.

TABLE 5 CLASSIFICATION OF TERRACES

Terrace	Vegetation	Physical features
4 (Highest)	Jesse bush	Large, unconnected areas with poorly defined limits
3	Mopane	Incised by streams
2	*Acacia albida*	Silty alluvium with indistinct watercourses and many pools
1a	Virtually unvegetated	Sandbanks capped by silt
1 (Lowest)	Virtually unvegetated	Shifting bars and banks of clean sand

The situation is not as simple as Stocklmayer's analysis might suggest. Although Nugent also feels that the alluvium lies in distinct terraces, he defines these somewhat differently, after field observations. Recent survey work done at Mana Pools by K.M. Dunham (National Parks Ecologist; pers. comm.) shows that a clear sequence of stepped terraces is not apparent in the few transects that he made at right angles to the Zambezi, towards the south.

For the purposes of this report, it is probably best to describe the alluvial areas along the middle-Zambezi simply as consisting of a complex of different deposits that vary in age, depth, texture, colour etc. and reflect past alterations in the river's channel. The most recent alluvial deposits are clean white sand and thin bands of grey silt along the present river channel. These deposits may become stabilized by vegetation such as Phragmites reeds and Vetiveria grass, and later by Acacia albida trees. Sedimentary structures found by Nugent in river cliffs formed at places where the Zambezi has eroded into old alluvium that supports well-developed A. albida woodlands indicate that this alluvium was deposited in conditions of variable current velocity, which would be expected in the channel of a river. Thus this alluvium was probably left along the old channels of the river, and blocks of evergreen, broad-leaved woodland between the A. albida woodlands represent old islands or levees that have reached a later stage in vegetational succession. The soil beneath some of the bordering mopane woodlands, to the south, contains laminated sedimentary structures that indicate deposition in low-energy environments only, and this soil has a high content of clay throughout its profile in contrast to the sandiness of the alluvium beneath A. albida woodlands. Therefore, while the A. albida alluvium was probably deposited within old channels of the Zambezi, the laminated clays found in some of the bordering mopane soils are possibly the result of overbank deposition that occurred when the river rose out of its old channels.

The supply of water and sediment to the Valley has changed in recent years; the total amount of water flowing into the Valley each year has increased (see 2.9.1) and the flow has been regulated to some extent, and sediment input reduced, by the Kafue and Kariba hydro-electric schemes (these schemes are not responsible for the increased inflow, and in fact have enhanced water loss due to evaporation, which is offset to some extent by increased rainfall in the Kariba area). The intakes of the Kariba turbines are situated at least 60 m above the base of the dam, and the floodgates are also very high. The water passing through the Kariba Dam therefore contains no

bed load and probably only a small suspended sediment component. Assuming that both the Kariba and Kafue dams act as complete sediment traps; then the sediment catchment area of the Valley now consists only of the Zambezi's water catchment area below the dams, which is less than 3 per cent of the former sediment catchment area. Two-thirds of the present sediment catchment area are underlain by well-consolidated Basement rocks, while the remainder (the Valley floor) consists of Karoo rocks. Although the Basement rocks are more resistant to erosion than are the sedimentary rocks of the Karoo System, the steeper slopes are invariably on the Basement rocks so the rate of erosion is probably greater on these; thus most of the sediment now brought in to the middle-Zambezi is probably derived from Basement rocks.

It appears that a major downstream effect of the Kafue and Kariba schemes has been to increase the rate of river erosion. Guy (1981) studied a stretch of about 40 km of the Zambezi, upstream of the Sapi mouth. He compared aerial photographs that had been taken of this stretch in 1954, 1965 and 1973, and found that over this study period 1030 ha of land had been lost in erosion while 210 ha were deposited as semi-permanent sandbanks.

Guy attributed the widening of the river to various factors:

i) the maintenance of a fairly constant water-level for long periods, through regulation by the hydro-electric schemes, causing notching of the banks, which later collapsed;

ii) the rapid flow of groundwater into the river, caused by sudden drops in the river-level when the floodgates at Kariba were closed abruptly, resulting in the collapse of the banks;

iii) out-of-season flooding in some years (e.g. 1963, 1966, 1969), caused by the opening of Kariba's floodgates during periods when the water-level would normally be low, reducing the effectiveness of the riverine vegetation in maintaining the stability of the banks;

iv) the clarity of the water leaving Lake Kariba, enabling increased erosion in the downstream stretches;

v) the erodibility of the sandy alluvial soils that extend along much of the middle-Zambezi's course, enhancing the above effects.

Nugent also used aerial photographs taken in 1954 and 1973, and assessed changes in the width of the middle-Zambezi's channel over this nineteen-year period. The widths of four stretches increased or decreased roughly as follows:

19 km stretch between Kariba Gorge and Lusito confluence = 18 per cent increase;

13 km stretch between Chirundu Bridge and Kafue confluence = 4 per cent decrease;

13 km stretch at Rukomechi confluence = 6 per cent decrease;

17 km stretch at Sapi confluence = 24 per cent increase.

Nugent feels that the river-widening in two of the stretches that he studied may be explained by the presence of relatively hard rock bars just downstream of each, which prevented the river from incising in as it has in the other stretches (i.e. erosion has occurred laterally rather than vertically).

It seems that the middle-Zambezi is presently in an erosive phase. One explanation for this is that the river has found a plane of weakness (fault?) in the hard rock of Mupata Gorge; this rock might previously have formed a local base-level, maintaining the gentle upstream gradient. Sediment input is now greatly reduced due to the construction of the Kariba and Kafue schemes so eroded material is not replaced, and the recent changes in the river's flow (i.e. increased volume, some regulation) probably also contribute to increased erosion. If the middle-Zambezi does in fact cut down further into the alluvial deposits, then its tributaries will be rejuvenated, and in eroding back along their courses the streams will drain the Mana Pools and other small pools just inland. Obviously, the process would be very slow in human terms although rapid on the geological time scale.

2.2.3 Effects of the Mupata Scheme in Relation to Erosion and Deposition

(Information derived largely from the contribution of Nugent, 1981)

The Impact of Wave Action on the Shoreline Most of the shoreline of Lake Mupata would cut mopane woodlands and jesse

thickets (see Fig. 5). The mopane soils above the Mana Pools alluvial system consist mainly of hard clay pans containing calcrete nodules and unidentified opaque crystals (see 2.3.1 for an outline of the soil types). The high proportion of exchangeable sodium ions (greater than 10 per cent of exchangeable cations) that is characteristic of mopane soils results in deflocculation of their clay content, making the soils mechanically unstable. The poor drainage, lack of vegetation cover, apart from mopane woodland, and inherent instability give rise to problems of sheet and gully erosion. It seems likely that a soil that is easily eroded by surface runoff would also be easily eroded by wave action on the lakeshore, although it is possible that the relatively high conductivity of the lake-water might promote some re-flocculation of the clay (K.W. Nyamapfene, Dept. of Land Management, University of Zimbabwe; pers. comm.). Where mopane soils formed steep soils on the edge of the lake, strong wave action and the fairly constant retention level of the lake might lead to undercutting beneath impervious soil horizons, so cliffs could develop.

The invariable sandiness of the soils beneath the jesse thickets that would be on the shoreline has been confirmed by augering, and a cliff on the Chiruwe River, cutting this soil type, shows 15 m of poorly-sorted, virtually unconsolidated sand with pebble beds at the base. Such sand would be quickly eroded and washed into the lake by wave action. Sandy beaches, and bars in shallow water, should develop. Nearer the entrance to Mupata Gorge, the soils are thin and overlie fairly well-consolidated Karoo sediments and Basement gneisses, so shoreline degredation should be much slower here. Severe erosion may occur along the shoreline in the vicinity of Chief Chiawa's village due to particularly strong wave action that would be likely here (see 2.1.2).

The Impact of Siltation The rate of siltation of Lake Mupata would be slow due to the trapping of sediment by the upstream dams. The time required for the dead capacity of Lake Kariba (116×10^9 m^3) to silt up is about 1 000 years (Olivier, in Bolton, 1978). This implies a rate of siltation of about 116×10^6 m^3 per year. The sediment catchment area of Lake

Mupata, being less than 25 000 km^2, can be taken as about 3,5 per cent that of Lake Kariba (720 000 km^2). Although there is no scientific justification for this, it may be assumed for the sake of argument that the rate of sediment input into each reservoir is roughly proportional to sediment catchment area (and that the prediction that Bolton quotes for Kariba's life-span is reasonable); this means that Lake Mupata would silt up at a rate of about 4×10^6 m^3 per year. With a minimum retention level of 375 m above sea-level, the dead storage capacity would be $12,4 \times 10^9$ m^3, so Lake Mupata might have a life expectancy of over 3 000 years. Despite the unsubstantiated nature of this reasoning, it is evident that the lake will not silt up within the sort of period considered by engineers and economists to be an acceptable operating life for such a scheme.

However, the likelihood of strong wave action along the shoreline, and the unconsolidated nature of much of the soil of the area, mean that a great deal of local sediment might be washed into the lake, thereby speeding the rate of siltation. Lake Mupata would narrow considerably just before entering Mupata Gorge; early siltation of this section could be caused by sediment input from tributaries that debouch here. On the Zimbabwean side, the Chewore and Mwanja rivers have catchment areas of 1 670 km^2 and 620 km^2 respectively, and on the Zambian side the Musensenshi River has a catchment area of 670 km^2, so these three major tributaries could bring in a considerable amount of sediment which might form deltas that would gradually advance.

Obviously, the construction of Mupata Dam would reduce the rate of siltation of Lake Cabora Bassa, although not by much. Bolton (1978) states that 15 per cent of this lake's water comes from the undammed Luangwa River, and a further 25 per cent comes from undammed rivers mainly off the cultivated Zimbabwean plateau, so these rivers probably carry a great deal of silt into the lake, apart from the Zambezi's contribution.

2.2.4 Mineral Potential of the Valley

(Information derived from the contribution of Anderson, 1981)

"Apart from speculative prospects of uranium and coal discoveries, the Zambezi is generally considered to have a low mineral potential compared to many other parts of the country. The Mupata gneisses and schists were examined briefly on two occasions in 1955 and then again in 1962. Occurrences of mica and kyanite were noted. A negligible production of mica has in fact been declared from the area. This implies some potential for other pegmatite minerals such as beryl, tantalite, cassiterite and wolframite. Apart from kyanite, a high-bulk low-value commodity, these minerals have been the traditional targets of smallworkers in other, more accessible, parts of the country. A possibility exists for deposits of copper, and perhaps lead and zinc, in these rocks since similar rocks in other parts of the country are mineralized by these metals in a few places."

"The Chewore Ignecus Complex was examined on the same occasions as the Mupata rocks described above, and was also examined in 1961-62 under an exclusive prospecting order (No. 94) granted to a subsidiary of Anglovaal Rhodesian Exploration Co. (Pvt.) Ltd., who prospected the north-easternmost exposure of the Complex whilst concurrently drilling the Mwanja Claims on the middle exposure. Investigations also included an unsuccessful aerial magnetic survey flown in 1955, and some ground scintillometer traverses over the gneiss terrain. Interest was centered upon platinum group metals : nickel, copper and chromite. Some encouraging surface indications of nickel and copper had been seen but further sampling and three diamond drillholes failed to disclose any subsurface mineralization. Chromite was located in situ in three places but this proved to constitute thin, isolated lenses of poor quality. Thin sub-economic stockworks of magnesite veins were reported as well as seams of valueless brittle fibre asbestos. More recent work on the Complex has been carried out by several claim-holders; although the results are not known they are presumed to be discouraging. Even if chromite,

magnesite or asbestos were found in the Complex in large ore-bodies, such deposits would certainly be less attractive than known deposits in the central parts of the country."

"The rest of the Valley, occupied by Karoo and younger rocks, contains no known mineral deposits. Coal may yet be found in the large sections of geologically unmapped terrain in this area. It is thought that in most parts any coal would be buried beneath younger sediments at depths that would be sub-economic for mining, but it is possible that in some places the coal measures may have been brought close to the surface as a result of the faulting that is common in the Valley."

"Recent interest has been shown in the potential for uranium deposits in the sedimentary rocks of the Valley; similar rocks in Zambia and other parts of Southern Africa are known to be mineralized by uranium. An investigation into this potential has begun, involving an airborne radiometric survey covering the entire Zambezi region between Wankie and Mukumbura."

2.2.5 Effects of the Mupata Scheme in Relation to Exploitation of Mineral Deposits

The Impact of Inundation "It appears that in the area of the Chewore Igneous Complex, the stretches of the reservoir extending up the Mwanja River and its tributaries would cover only small, marginal patches of the north-eastern and central outcrops of the Complex. The gneisses and schists nearby, which almost invariably form high ground, would not be drowned apart from a thin strip along the walls of the Mupata Gorge itself. The Karoo and younger sediments extending upstream from the Mwanja mouth are not known to contain any mineral deposits whatsoever along the narrow belt of country that would be flooded. Loss of mineral potential resulting from submergence is therefore assessed to be negligible."

The Impact of Facilities Associated with the Mupata Scheme "A major factor in all prospecting operations

is that of ease of access to target areas. Damming the Zambezi at Mupata would require a good road to the dam site, which is situated in the mid-northern part of the terrain of gneisses and schists described above. The road would no doubt stimulate some smallworker prospecting for pegmatite and other minerals in these parts. Access to the Chewore Igneous Complex would be provided by the dam waters themselves and may encourage some further exploration of these rocks. Uranium prospecting in the Valley will almost certainly be completed before the implementation of the Mupata scheme and need not be considered further. Coal exploration will undoubtedly be conducted in the Valley sometime in the future whether the Mupata scheme is implemented or not. However, the improved road and water access that would result from damming the river would reduce the costs of prospecting and perhaps encourage such an exercise to be mounted sooner."

"Mica, beryl, tantalite, tin and wolframite deposits in the gneiss/schist terrain (if discovered) are likely to be operated as short-lived smallworkings, which normally do not justify expensive power connections nor piping of water over large distances. Thus electricity and water from the scheme would probably have little impact on the mining of such deposits. The possibility of kyanite deposits is of academic interest only since huge reserves, that could support many decades of mining, are known much closer to the existing national infrastructure. It is faintly possible that economic nickel, copper and platinum mineralization may yet be found in the Chewore Igneous Complex. The exploitation of such deposits would be facilitated by local sources of power and water and by an improved regional infrastructure."

"The effects of the scheme on any coal or uranium deposits would depend very much on where the deposits were located. The scheme's supply of power would be the most important factor assisting mining of these materials, whereas water could probably be obtained quite economically at most sites by tapping the Karoo's normally high content of groundwater. It is unlikely that secondary roads

built to serve tourist and hunting interests along the lake would be adequate to carry the transport involved in large-scale mining operations, so roads capable of handling heavy traffic would have to be specially constructed. The profitable exploitation of coal would certainly have to await a connection to the national rail network. This rail connection would not come about as a result of the Mupata scheme per se"(it might possibly come about through the alignment of a new Lusaka-Salisbury link across the dam wall). " Since the merits of any discovered coalfields in the Valley are most unlikely to outweigh the factors favouring development of the coals in the north-west of Zimbabwe, it is probable that there will be no coal-mining in this region for decades."

"It must be pointed out that in the above impact assessment the restraints imposed upon prospecting and mining in National Parks and Safari Areas have been ignored."

2.2.6 Seismicity in the Mupata Gorge Area

(Information derived from Merz and McLellan, 1981, and the contribution of Allen and Torrance, 1981)

In the vicinity of the dam site, the old rift of the Luangwa Valley forks east towards Cabora Bassa and west towards Kariba. The Mupata Gorge area experiences a low to moderate amount of shallow seismic activity each year; earthquakes of magnitudes less than $M_s = 3$ commonly occur, although events up to $M_s = 4,6$ have been recorded during the period 1966 to 1980. A single event of $M_s = 6,1$ is reported to have occurred on 10 March, 1969, with an epicentre only some 20-30 km from Mupata Gorge.

2.2.7 Seismic Effects of Lake Mupata

(Information derived largely from the contribution of Allen and Torrance, 1981)

The load of water contained in a large man-made reservoir, and hydraulic pressure in pore spaces and fractures, may trigger the sudden release of existing tectonic stress in the local rock. The pattern of seismicity that has been observed in

the vicinity of such reservoirs is:

i) a low level of seismicity, in regions containing pre-existing weaknesses in otherwise competent rock, prior to the building of the dam;

ii) weak but persistent activity commencing soon after impoundment;

iii) outbursts of intense activity, about three or four years later, accounting for almost all the seismic activity released;

iv) activity continuing at a gradually decreasing level for a long period, eventually settling to a level higher than the pre-impoundment level.

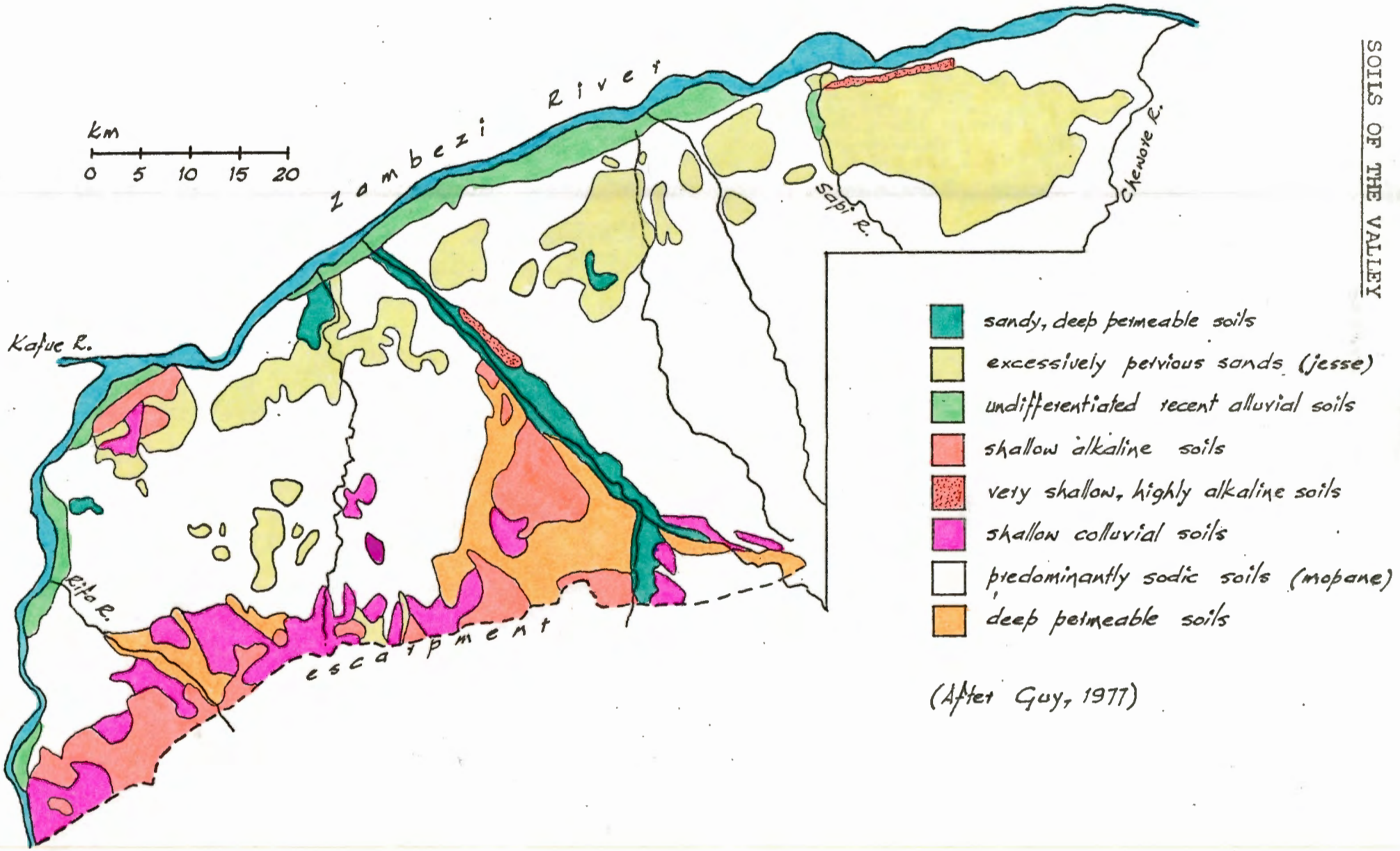
Since the site of the Mupata dam is so close to a fork in the rift valley, and the rocks are probably stressed, seismic activity might occur according to the usual pattern following impoundment. It is not thought that lakes Kariba, Mupata and Cabora Bassa would have a cumulative seismic effect. Lake Cabora Bassa has caused some weak seismic activity but the stage of intense activity has not yet occurred here. This may yet happen, but the likelihood is small. It would not be prudent to assume that Lake Mupata would also have such mild seismic effects, since strong shocks have occurred at Lake Kariba, but the most intense activity is unlikely to exceed $M_s = 6$ and there is little risk of damage to the wall.

2.3 SOILS AND IRRIGATION POTENTIAL

2.3.1 Soils of the Valley

Thompson (1958) and Henderson and Griffiths (1959) carried out reconnaisance soil surveys in the Valley from Kariba Gorge to the Chewore River. Their work was orientated towards assessing the irrigation potential of the Valley. Most of the information on soils given below is derived from their reports.

Soils developed on the Triassic formations of the Karoo System cover most of the Valley. They vary to some extent depending on the series from which they were derived, but in general consist of fine- to medium-grained sands in the surface horizons, overlying compacted, strongly-alkaline horizons which are usually almost impervious. The most commonly occurring Triassic sandstones are known to contain a fair proportion of unweathered minerals rich in sodium, and these would appear



SOILS OF THE VALLEY

FIG. 4

to have contributed to the development in situ of sodic soils; large areas of these sodium-affected soils are unrelated to drainage systems arising in the Escarpment and so, in such areas at least, runoff from sodium-rich paragneiss of the Escarpment could not have brought about the present sodic soil conditions by a process of illuviation. Around the Chewore River, the Triassic sandstones form a complex of ridges, extending down to the Zambezi, on which soils are very skeletal. Mopane is the dominant tree on these widespread sodium-affected and skeletal soils, which may thus be referred to as "mopane soils". In some places, such as along the Rukomechi River, the ground is sometimes bare due to an accumulation of salts that is too excessive even for Mopane, or may have a sparse cover of plants such as Hyphaene and Salvadora if a thin layer of sand overlies the impervious layer.

Extensive mounds of reddish soils derived from the aeolian sandstone of the Upper Triassic are found mainly in the northern half of the Valley. These are deep, fine- to medium-grained sands which tend to be leached of bases and therefore acidic, and have a low available water capacity. They may be referred to as "jesse soils"since they are invariably covered by jesse vegetation.

The flattest areas of the Valley are those along the base of the Escarpment where colluvial soils have developed. These vary somewhat depending on the source and age of the deposited material, but are usually deep, with brown fine- to medium-grained loamy sands overlying sandy clay loams or clay loams. Right near the Escarpment the depth of the soils may be limited by paragneissic stones.
Alluvial deposits are confined to the larger rivers such as the Zambezi, Rukomechi and Sapi. The younger alluvia vary in texture but are generally very sandy, resulting in rapid permeability and poor available water capacity. The older alluvia are similar to the soils of colluvial origin, being deep with a greater content of clay. (The nature of the alluvial deposits along the Zambezi is discussed in 2.2.2)

The soils east of the Chewore River have not been studied.

Some hills around the Mwanja River are covered by small tree savanna similar to that of the Great Dyke and it is likely that the skeletal soils of these hills are derived from dunite, which is known to release toxic concentrations of some elements.

2.3.2 Irrigation Potential of the Valley

The colluvial and older alluvial soils near the Escarpment have the most potential for irrigation of the soils of the Valley since they are often fairly deep with good permeabilities and adequate available water capacities. However, as mentioned, stoniness may reduce the potential of some of the colluvial soils, and other colluvial soils have silty horizons which may compact, thus reducing permeability. The compacted sodic horizons of the mopane soils and/or their shallowness render them quite unsuitable for irrigation. The jesse soils are excessively pervious and inherently infertile. The alluvial soils along the Zambezi are very variable and are susceptible to seasonal waterlogging.

The only attempt at commercial irrigation in the Valley was the establishment in 1953 of the Chirundu Sugar Estates on alluvial soils near Chirundu, where about 680 ha were estimated to be suitable for continuous cropping under sprinkler irrigation. Sugar cane was produced in significant quantities from 1960 onwards. By 1966, there were about 4 000 people on the Estate but in this year it was decided to cease production due to financial losses. Problems included high transport costs, severe eelworm infestations in the sandy soils, a low world price for sugar in the mid-1960's and the inability to compete with the higher cane yields of the south-eastern Lowveld. The soils were thought to be suitable for cotton, groundnuts and seed beans but production of these crops was not worthwhile.

2.3.3 Irrigation Potential with Lake Mupata

The soil types that would be flooded are of varying significance. The patches of alluvium along the Zambezi would be lost and the only remaining extensive areas of irrigable land would be near the Escarpment, where the reasonably fertile colluvial and older alluvial soils occur. However, water would have to be pumped 25 km or more from the lake, and in fact the distance from the

Zambezi River to these irrigable soils is only slightly greater. Thus, overall, the creation of Lake Mupata would probably diminish rather than increase the irrigation potential of the Valley, which is low anyway.

2.4 VEGETATION

(Information derived from the contribution of Muller and Pope, 1982)

2.4.1 Vegetation of the Valley

"Available classifications and descriptions of the vegetation of the Valley (Guy, 1977; Wild, 1965) were found to be inadequate for the purposes of this report and it was considered necessary to conduct a brief vegetation survey. Because time was limited (18th to 28th September, 1981), the classification resulting from the survey must be regarded as preliminary."

"The area investigated is bounded by the Nyakasanga, Zambezi and Mwanja/Chiraradzi rivers and by an arbitary line running more or less parallel to the Zambezi, taken from a point about 30 km south of the Nyakasanga confluence to a point about 20 km south of the Mwanja confluence; this area is some 2 500 km^2 in extent."

"Using 1:50 000 aerial photography, the vegetation was stratified into apparently homogeneous units. Eighty-two plots, representative of the different vegetation units, were assessed by listing the woody species and recording their cover abundance, using a Braun Blanquet scale. As a check on the air photo interpretation of boundaries between vegetation units and the actual classification of these units (by their species composition) a further seventy points were briefly sampled. This was done by listing the important species and locating the points checked on the air photographs. An additional check on the accuracy of the initial stratification and vegetation boundaries was made by comparing them with a false-colour satellite photograph of the area."

"The data obtained in the survey were insufficient for a computer analysis and the following ten major vegetation types have therefore been derived subjectively from field sheets. The first three are of considerable extent, while the areas of the remainder are

smaller.

i) The riparian vegetation on alluvium.
ii) A mixed species layered dry forest (jesse bush).
iii) Colophospermum woodland.
iv) Combretum/Terminalia/Diospyros kirkii wooded grassland.
v) Colophospermum/Kirkii/Terminalia prunioides woodland on ridges.
vi) Mixed species woodland on larger hills.
vii) Acacia robusta/Terminalia prunioides woodland.
viii) Mixed Acacia/Lonchocarpus capassa open woodland.
ix) Vegetation associated with alkaline pans.
x) Grassland."

"Brief descriptions of these vegetation types are as follows.

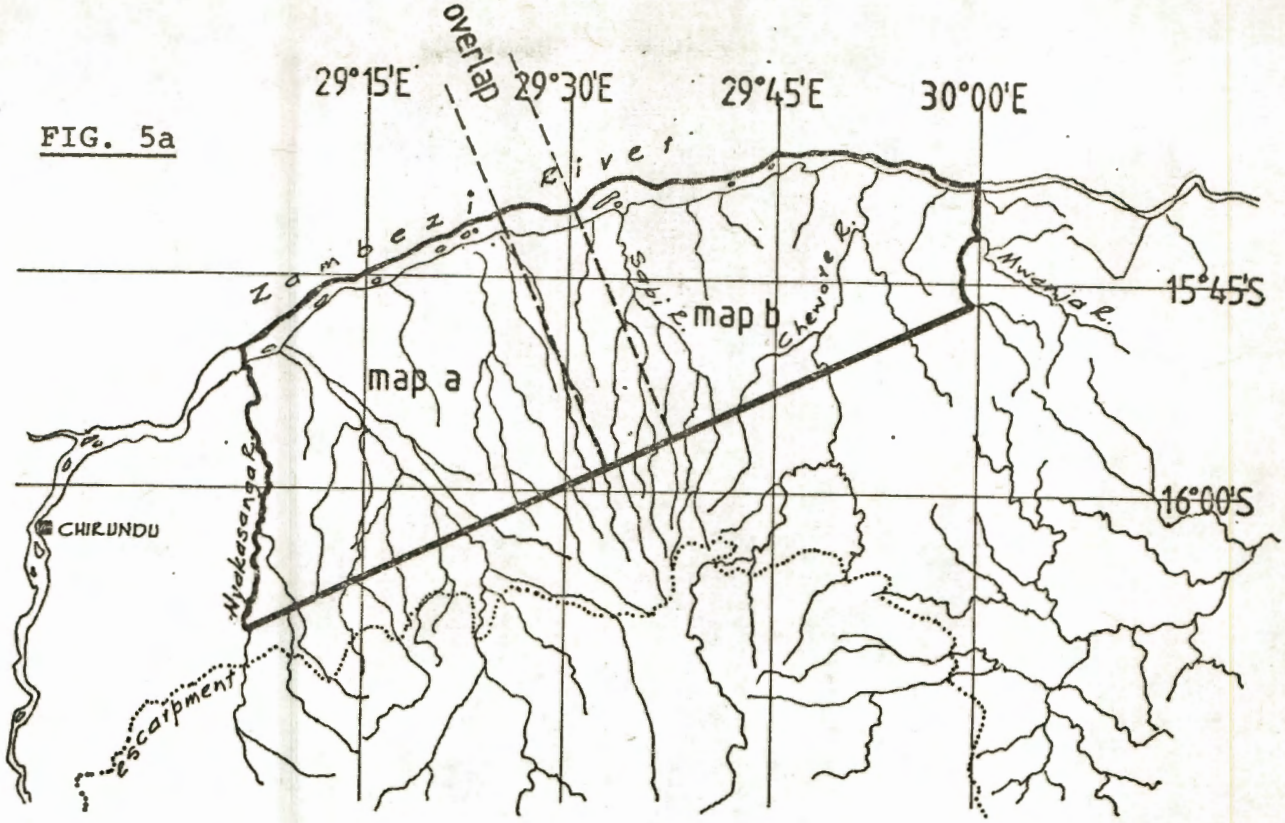
i) Riparian vegetation on Zambezi alluvium

Where undisturbed, the riparian association consists of well-grown trees often with an almost continuous canopy. An understorey of shrubs is present in all except some pure stands of Acacia albida in the early stages of succession or in Acacia albida occurring on clayey soil in depressions. Animal pressure has opened up the canopy and reduced the shrub cover over much of the flood plain, and is also retarding regeneration of many species.

Four more or less distinct vegetation types, determined by the physical nature, age and height of the alluvial deposits can be distinguished. However, since they are difficult to demarcate on aerial photography (often grading into each other) they have been mapped as one unit. Numerous changes in the river course have brought about a complex pattern of vegetation types in which the oldest stage is not necessarily furthest from the river. The four types are as follows.

Acacia albida woodland This is Acacia albida colonising the relatively loose sand banks of the islands and the lower unstable river terraces. It comprises almost pure stands of A. albida showing age structure. There is little or no woody understorey.

FIG. 5a



R	Riparian vegetation on alluvium.
J	Mixed species layered dry forest (jesse bush).
M	Well-grown *Colophospermum mopane* woodland.
MU	Well-grown *Colophospermum mopane* woodland with understorey.
MS	*Colophospermum mopane* scrub.
WG	*Combretum/Terminalia/Diospyros kirkii* wooded grassland.
K	*Colophospermum/Kirkii/Terminalia prunioides* woodland on ridges.
H	Mixed species woodland on larger hills.
WA	*Acacia robusta/Terminalia prunioides* woodland.
O	Mixed *Acacia/Lonchocarpus capassa* open woodland.
S	Vegetation associated with alkaline pans.
G	Grassland.

scale: km 0 5 10 15

KEY TO VEGETATION MAPS

FIG. 5b

VEGETATION MAP a

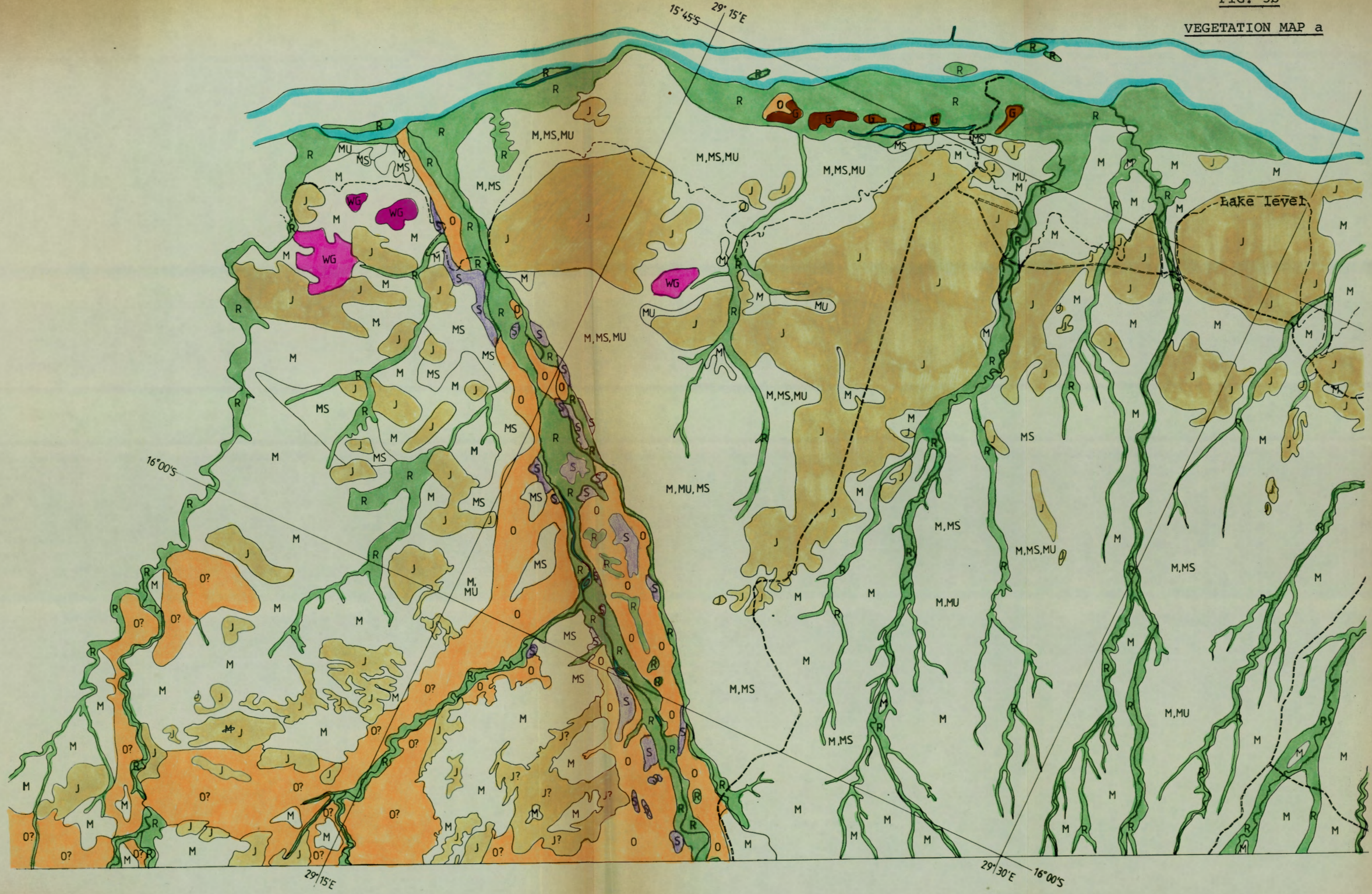
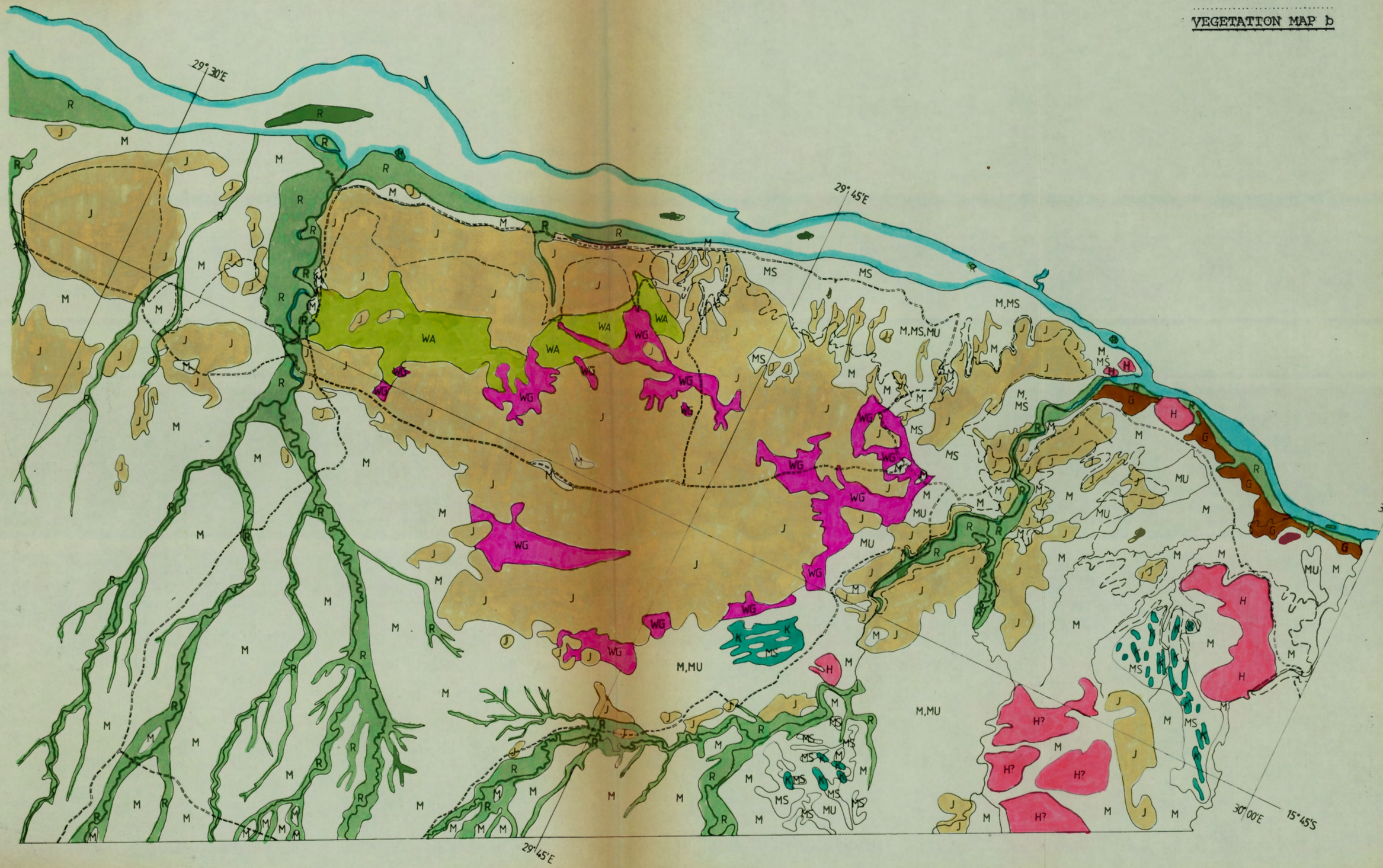


FIG. 5c

VEGETATION MAP b



Acacia albida dominated woodlands Developed from the vegetation type above, this is dominated by Acacia albida which can have a cover abundance of 60-80 per cent. However, other tree species such as Combretum imberbe, Kigelia africana, Lonchocarpus capassa and Trichelia emetica have become established.
The shrub layer, although sometimes absent or comprising only patches of Diospyros senensis is often well developed and consists of Allophylus alnifolius, Cardiogyne africana, Combretum paniculatum subsp. microphyllum, C. obovatum, Grewia flavescens var. olukondae, Securinega virosa and occasionally shrub forms of Hyphaene benguellensis var. ventricosa.

Mixed Acacia albida/Combretum imberbe/Kigelia africana/Lonchocarpus capassa woodland The species used to describe this woodland occur in more or less equal proportions. Other common trees are A. nigrescens, Cassine schlechterana, Cordyla africana, Diospyros mespiliformis, Ficus sansibarica, Garcinia livingstonei, Piliostigma thonningii and Tamarindus indica.
The shrub layers also show a greater mixture and frequency of species than do the above two vegetation types. The common large shrubs include Cardiogyne africana, Cleistochlamys kirkii, Diospyros senensis and Oncoba spinosa. The smaller shrubs are Combretum mossambicense, C. obovatum, C. paniculatum subsp. microphyllum, Dichrostachys cinerea, Friesodielsia obovata Grewia flavescens var. olukondae and Securinega virosa. Climbers become important in this vegetation type and Combretum paniculatum, Artabotrys brachypetalus, Capparis tomentosa, Dalbergia arbutifolia and Tiliacora funifera are found here. These vegetation types can be found along the high banks (levees) of old river channels, often with A. albida dominant in the adjacent depressions.

Mixed riparian woodland This can be considered to be the most mature of the riparian vegetation types of the alluvial system. It has a greater species diversity than the preceding types and contains some components of the non-alluvial communities, e.g. Colophos-

permum mopane, Adansonia digitata and Sterculia africana. A. albida is normally absent and, while there is no really dominant tree species, Combretum imberbe and Lonchocarpus capassa can become locally dominant. The main tree species of this type are A. nigrescens, A. robusta subsp. clavigera, A. tortilis, Combretum imberbe, Cordyla africana, Diospyros mespiliformis, Ficus sansibarica, Garcinia livingstonei, Kigelia africana, Lonchocarpus capassa, Piliostigma thonningii, Xanthocercis zambesiaca, Tamarindus indica and Xeroderris stuhlmannii. The small trees include Cassine schlechterana, Cardiogyne africana, Cleistochlamys kirkii and Diospyros senensis. The more common shrubs are Allophylus alnifolius, Combretum mossambicense, C. obovatum, C. paniculatum subsp. microphyllum, Friesodielsia obovata, Grewia flavescens var. olukondae and Pavetta gardinifolia. The climbers are Combretum paniculatum, Capparis erythrocarpos, C. tomentosa, Strophanthus courmontii and Tiliacora funifera. Vegetation of this type is best represented on well-wooded gentle ridges and slopes, and extends down to the lower alluvial deposits. Where it occurs on flatter ground, it often contains open areas.

The vegetation on the lower reaches of the Zambezi tributaries is essentially similar to that of the Zambezi alluvial system. However, the four vegetation types outlined above are rarely individually extensive and tend to be more intermixed. One noticeable difference is that Croton megalobotrys is common along the larger tributaries but was not recorded along the Zambezi. Going up the rivers, the alluvial vegetation narrows down to a fringe of riparian woodland. As the river becomes smaller, species that are found towards the outer edge of the fringe in the downstream sections occur closer to the water-course. Typical alluvial species become less numerous and species such as Kirkia acuminata and Terminalia prunioides take their place. Apart from the Rukomeche and the Nyakasanga riverine communities, extensive Acacia albida stands are not common along the tributaries. Much of the vegetation along the Rukomeche and some of the Chewore rivers has been modified by past cultivation.

Generally speaking, animal utilization does not seem to be excessive.

ii) Mixed species layered dry forest (jesse bush) This can be considered to be a type of dry deciduous forest with a thicket-like understorey. It is relatively rich in both tree and shrub species and is found only on deep sands. Several types of this association can be recognized on the ground and easily identified on the false-colour satellite photograph of the area, but in this report the jesse bush is treated as one association. More field work, including a thorough investigation of the environmental factors, is needed before the jesse bush can be divided into vegetation sub-types. Tree species common to almost all jesse bush types are Xeroderris stuhlmannii, Pterocarpus lucens subsp. antunesii, Commiphora karibensis, Pteleopsis myrtifolia, Xylia torreana, Berchemia discolor, Lannea schweinfurthii, Schrebera trichoclada, Lonchocarpus bussei. Thicket-forming species of almost all jesse bush types are Combretum celastroides, C. elaeagnoides, Friesodielsia obovata, Baphia massaiensis, Acacia ataxacantha and Cleistochlamys kirkii. The following species are common or even dominant in certain types of jesse bush but are absent in others: the tree species Combretum apiculatum, C. collinum, Kirkia acuminata, Entandrophragma caudatum, Colophospermum mopane, Commiphora ugogensis, Acacia robusta subsp. clavigera and A. nigrescens;
and the shrub species Combretum mossambicense, Meiostemon tetrandrus, Vangueria infausta, Holmskioldia tettensis and Croton scheffleri.
Selective destruction, mainly be elephants, of some canopy trees (especially Commiphora and Combretum spp.) gives the jesse bush a thicket-like appearance in places. A considerable number of fallen trees were observed in some areas. In other areas, mature trees are practically absent, although there was little evidence of recent disturbance, and the shrubs and young trees combined to form a thicket.

iii) Colophospermum mopane woodland This is the

most extensive vegetation association on the Valley floor. It is a woodland type where the canopy trees consist almost exclusively of closely-spaced Colophospermum mopane. It is found on the poorly-drained clay soil associated with the floodplain and on shallow gravel soils elsewhere. There is often an abrupt change from mopane woodland to the adjacent vegetation types, but gradual changes have also been observed. The mopane woodlands are easily subdivided as follows.

Well-grown mopane This consists essentially of Colophospermum mopane trees with a sparsely-developed shrub layer in which young mopane is dominant. Other occasional tree species are Acacia robusta subsp. clavigera, A. nigrescens, Terminalia prunioides, Erythroxylum zambesiacum, Commiphora mollis, Combretum apiculatum and Drypetes mossambicensis. Typical shrub species of good mopane are Boscia mossambicensis, B. matabelensis, Commiphora africana, C. pyracanthoides, Courbonia glauca, Ximenia americana, Canthium frangula, Holmskioldia tettensis and Balanites aegyptiaca. Near the alluvial system this type of mopane woodland is heavily degraded in places and the cover abundance of the canopy trees is reduced to as little as 10 per cent. The degradation is extremely patchy. Mopane woodland on gravel soils away from the alluvial system does not seem to be excessively utilized by game.

Mopane with understorey Dense understorey is often developed in mopane woodland adjacent to either jesse or riparian communities. In the proximity of alluvium, Acacia robusta subsp. clavigera and A. nigrescens become more numerous in the canopy layer and scattered Lonchocarpus capassa and Boscia mossambicensis are to be found. The common species of the understorey are Friesodielsia obovata, Combretum elaeagnoides, C. obovatum and Boscia mossambicensis. Near the jesse bush the following species of trees are observed in the mopane woodland: Combretum apiculatum, Commiphora ugogensis, Schrebera trichoclada and Xeroderris stuhlmannii. Typical understorey species are Combretum elaeagnoides, Friesodielsia obovata, Holmskioldia

tettensis, Dichostachys cinerea and Acacia ataxacantha. A third understorey type is found on the low ridges in the Chewore area, where mopane occurs with a relatively dense understorey of Croton menyhartii, Acacia ataxacantha, Boscia mossambicensis and Gardenia resiniflua. The tree species found with the mopane are Commiphora merkeri and Kirkia acuminata.

Scrub mopane This occurs mainly on the edges of the Zambezi alluvial system and also between the densely-wooded ridges in the Chewore area. The mopane trees here are only up to 3 m in height, forming relatively dense stands with much bare soil and interspersed with incipient pans. Associated but very scattered species in scrub mopane, at the edges of the alluvial system, are Hyphaene benguellensis var. ventricosa, Boscia matabelensis and Terminalia prunioides. Scrub mopane away from the alluvium contains few associated species. Scrub mopane in the vicinity of the alluvium is often heavily degraded by game.

iv) Combretum/Terminalia/Diospyros kirkii wooded grassland This association is typified by scattered trees in open grassland. Characteristic tree species are Combretum apiculatum, C. zeyheri, Terminalia stuhlmannii, T. stenostachya, T. brachystemma, Diospyros kirkii, Dalbergiella nyasae and Crossopteryx febrifuga. Colophospermum mopane may be present in various proportions or be entirely absent, and gradual changes from mopane woodland to this association can occur. The shrub layer consists mainly of shrubby forms of some of the tree species with the addition of Combretum elaeagnoides. At least three vegetation types can be recognized within this association, each characterized by certain species. One type is found on pebbly basalt hills of the Nyakasanga area, another is found on sandy soils along drainage lines in the vicinity of jesse bush, and the third type occurs on the more open area associated with gentle ridges within the extensive mopane belt between the jesse bush and the southern Escarpment. However, these three types have the more important tree species

in common and are treated as a single association in this report. Extensive degradation of this wooded grassland was observed in the areas along the drainage lines.

v) Colophospermum/Kirkia/Terminalia prunioides woodland on ridges This is a woodland of closely spaced trees with a fairly dense shrub understorey. It is confined to low sandstone ridges which occur within the mopane woodlands of the Chewore area. Colophospermum mopane can be the dominant tree with Kirkia acuminata and Terminalia prunioides co-dominant where this association is best developed. Other tree species are Lannea stuhlmannii, Diospyros quiloensis, Combretum apiculatum, Sterculia africana, Entandrophragma caudatum. Characteristic shrub species are Croton menyhartii, Gardenia resiniflua, Commiphora pyracanthoides, C. merkeri, C. africana, Acacia ataxacantha and Combretum elaeagnoides.

vi) Mixed species woodland on larger hills All vegetation occurring on the larger hills in the Chewore River area is included in this association. It is generally well-treed with a relatively dense shrub layer, but in some areas (usually where the terrain is flatter) a more open woodland can occur. Several vegetation types may be grouped under this heading, but more detailed examination is necessary for further subdivision. Typical tree species are Combretum apiculatum, Diospyros quiloensis, Croton gratissimus, Sterculia quinqueloba, Commiphora mollis, Pteleopsis myrtifolia, Dalbergiella nyasae, Colophospermum mopane, and, on flatter areas, Diospyros kirkii and Pterocarpus brenanii. Commiphora marlothii is very common on the steep broken slopes, while Kirkia acuminata and Afzelia quanzensis occur on the lower slopes only. Typical shrub species are Combretum elaeagnoides, C. mossambicense, Gardenia resiniflua, Holmskioldia tettensis, Combretum celastroides, Friesodielsia obovata, Commiphora pyracanthoides, C. africana, Hippocratea buchananii and Croton scheffleri.

vii) Acacia robusta/Terminalia prunioides woodland This is a woodland consisting of scattered clumps of trees with shrubs growing on a hard white soil exposed in numerous bare areas, with scattered incipient pans. It is only found east of the Sapi River, where it is surrounded and interspersed by jesse bush. Besides Acacia robusta subsp. clavigera and Terminalia prunioides, there are to be found occasional trees of Acacia nigrescens, Diospyros quiloensis, Lonchocarpus capassa, Manilkara mochisia, Cordia goetzei, Boscia mossambicensis and Croton gratissimus. The dominant shrub species is Croton menyhartii, but scrub forms of Acacia robusta, A. ataxacantha and Terminalia prunioides are also common. Other shrub species are Commiphora pyracanthoides, Boscia mossambicensis and B. matabelensis. This woodland is fairly heavily utilized by game and shows some degradation.

viii) Open mixed Acacia/Lonchocarpus woodland This is a woodland of scattered trees and dense clumps of shrubs separated by open areas which may be fairly extensive. Vegetation has been severely affected by past habitation and cultivation which took place on the Rukomeche alluvium and also on the deep soils between the Nyakasanga and Rukomeche rivers. The tree species are Acacia tortilis, A. robusta subsp. clavigera, A. nigrescens, Lonchocarpus capassa and Cordyla africana. Xanthocercis zambesiaca and Ficus zambesiaca occur in some areas. The common shrub species are Combretum mossambicense, Capparis tomentosa, Diospyros senensis, Dichrostachys cinerea and Combretum elaeagnoides. A detailed examination of this woodland type would probably separate the vegetation associated with the alluvium of the Rukomeche River from that of the deeper soils away from this river. These two types are treated here as one because of the apparent similarity brought about by a past history of cultivation.

ix) Vegetation associated with alkaline pans This vegetation type is recognized by dense clumps of mainly evergreen shrubs scattered over large bare areas

which contain pan-like depressions. Trees are practically absent except for the occasional Acacia robusta subsp. clavigera and Hyphaene benguellensis var. ventricosa. The clumps of shrubs are mainly Salvadora persica, but Combretum obovatum and Capparis tomentosa also occur.

x) Grasslands These are fairly extensive areas, devoid of woody vegetation, found near to Mana Pools and east of the Chewore confluence, and also in the many smaller unmapped patches scattered through the Zambezi alluvial system. Since the field work was carried out in the dry season, no species list was possible. The areas east of the Chewore confluence are apparently related to old cultivation and dense stands of Dichrostachys cinerea are often associated with it. The drainage lines are sometimes fringed with Acacia kirkii. The grasslands in the vicinity of Mana Pools are more vlei-like and according to Guy (1977) are related to the montmorillonitic clays."

2.4.2 Impacts of Lake Mupata on Vegetation

"The vegetation through which the shore-line would pass consists mainly of some mopane woodland and jesse bush. To make a detailed assessment of the probable effect of the water-body on the marginal areas it would have been essential to look at the Lake Kariba shore-line. However, this was not possible and the following comments have to be regarded as rather general."

"Effect on the areas between high and low water-level marks The flatter the country, the further a shore-line will recede with a drop in lake-level. Since the Lake Mupata shore-line would pass through land of low relief for much of its length, the area affected by fluctuating lake levels would be considerable. Assuming an expected fluctuation of 1 m , the draw-down zone would often be between 50 and 200 m wide. All existing vegetation would eventually be killed by the process of intermittent flooding. The herbaceous cover and some of the woody species such

as Adansonia digitata, Sterculia spp. and probably Commiphora spp. would die during the first period of submergence. Other woody species such as Colophospermum mopane, Kirkia acuminata and various Combretum spp. can survive a certain amount of flooding over a limited period (Jarman, 1968) and would probably live for a few years under the conditions of a fluctuating lake-level. The period of survival would depend upon the duration and depth of flooding as well as on the size of the trees (Jarman, 1968). The area exposed by the receding water would eventually be bare of the original vegetation, but would be recolonized by plants especially adapted to fill this niche."

"Probable effect on the vegetation of areas adjacent to the high water-level mark. Along the shore-line would be a relatively narrow zone where the soil is permanently waterlogged (soak zone), which would be occupied by swamp plants; the composition and extent of this community would depend to a large degree on the rate at which the water-level changed. In the mopane woodland a so-called green zone, stretching from the high water-level mark to approximately 1,5 km inland, would develop. In this zone the mopane trees would retain their leaves due to the rise in water-table (Jarman, 1968). At Kariba, the vegetation in this belt was extensively damaged by increased animal pressure (Jarman, 1968). From general observations at Lake Kariba it can be assumed that there would be little initial change in the vegetation where jesse bush occurs along the shore-line. To predict whether or not a riparian fringe would establish itself, and the length of time needed to do so, requires study of the soils along the shore-line, the new water-table and the autecology of the plant species concerned. Judging by observations made at other man-made lakes, the establishment of a riparian fringe is an extremely slow process. At Kariba, for instance, there is very little evidence of it after 24 years."

"The probable effect on the vegetation beyond the shore-line The vegetation beyond the direct influence of the water-body would be only indirectly affected by the proposed dam by virtue of the use to which this land would be put. Existing vegetation should be considered together with all other factors when decisions on the future land use of this area are made. For this reason the vegetation map produced with this report covers a substantial proportion of the land adjacent to the proposed dam. Apart from assisting with these decisions the vegetation map and classification will also provide the basis for a resource assessment should the area continue as a National Park, or for land use planning should human settlements be considered."

2.5 TERRESTRIAL INVERTEBRATES

(Information derived from the contribution of Phelps, 1981)

2.5.1 Terrestrial Invertebrates of the Valley

"Detailed knowledge of all the terrestrial invertebrates in the area between the Zambezi River and the game fence south of the Zimbabwean escarpment does not exist. The low level of human disturbance in the Valley has meant that the habitat of the terrestrial invertebrates has been almost undisturbed, apart from changes due to natural causes such as fire, seasonal events, varying patterns of habitat change due to feeding by mammalian herbivores, and long-term variation in the vegetation patterns. In this situation, the terrestrial invertebrate communities are in a constant state of change in relative numbers of the different species, and it is not possible to make a definite statement on what the situation is without a really long-term study."

"The Valley is, to some degree, an extension of the Mocambique faunal area; some terrestrial invertebrates with affinities to that region extend their ranges into Zimbabwe up the Zambezi (e.g. some Tabanidae)."

On a collecting trip to the Sapi/Zambezi confluence in August, 1981, D.L. Hancock (Curator of Invertebrates, National Museum of Zimbabwe) collected several insects that were of particular interest. Celidodacus sp. n. and Stephanotrypeta sp. n. are two flies, of the family Tephritidae, that are undescribed as yet; the former is known only from this locality. Goniurellia munroi Friedberg and Brachiopterna ornithomorpha (Munro), also members of the family Tephritidae, were recorded for the first time in Zimbabwe. Dermaleipa arcifera Hampson is a nocturnal moth, of the family Noctuidae, that is regarded as being an East African species, and has been found in Zimbabwe only at the Rukomechi and Sapi mouths. The butterfly Charaxes cithaeron joanae Van Someron is a rare Zambian subspecies of the family Nymphalidae; this subspecies is known in Zimbabwe only from the Sapi/Zambezi confluence, although a different subspecies occurs in the forests of the Eastern Districts.

This collecting trip cannot be regarded as a representative survey of terrestrial invertebrates in the Valley since only a few insect groups were studied, briefly, in a restricted area; the findings indicate that more detailed entomological work would be worthwhile.

2.5.2 Impacts of the Mupata Scheme on Terrestrial Invertebrates

The Impact of Inundation and Water Control

"Inundation of the riparian fringe of the Zambezi will undoubtedly destroy some invertebrate habitats, but somewhat similar riparian habitats exist (to a far lesser extent) on the tributaries of the Zambezi (such as the Nyakasanga, Rukomechi, Sapi and Chewore). Terrestrial invertebrates from the Zambezi-type riparian habitats will thus be reduced in number, but species are unlikely to be eliminated. The species diversity over the Valley will therefore not be reduced and, as the Zambezi's riparian fringe forms only a small part of the Valley, the overall impact on terrestrial invertebrates will not be great. If the invertebrates are members of the Mocambique faunal community, then the reduction of some of these species at the limit of their range cannot be considered a major environmental impact. New invertebrate habitats will be created with the impoundment, and this may result in an increase in species diversity."

"Although the draw-down of the lake will probably not often exceed 3 m, in the flat terrain of much of the Valley this would result in alternate exposure and flooding of a considerable section of land. Terrestrial invertebrates will re-invade new habitats only to be destroyed by the rising waters in due course. The extent of this fluctuation in animal numbers will be small in relation to the populations of the Valley. The same sort of situation occurs on the margins of Lake Kariba. Many aquatic insects will increase in numbers with the flooding, and the adult stages may become a nuisance around settlements."

"Redistribution of the terrestrial vertebrates as a result of the impoundment will affect the distribution of the blood-sucking invertebrates such a tsetse flies, horse flies and ticks."

The Impact of Construction Camps and Permanent Townships

"The impact of construction camps and permanent townships will be localised, but in such localities it may be considerable. Application of pesticides for the control of vectors of malaria and sleeping sickness may have considerable effects on the numbers of invertebrates. At Kariba it was necessary to treat about 100 square kilometres with pesticide to protect the township against the vector of sleeping sickness. Depending on what pesticide is used and how it is applied this level of application may have short- or long-term effects on other invertebrates. Insects, other than bloodsuckers, already present in the Valley will become a nuisance to people in newly-developed settlements. An example is the problem of stinkbugs coming into houses at night, especially when the houses are situated on hill tops. Again, attempts will probably be made to control these with insecticides, with adverse effects on other invertebrates. The areas of permanent settlement are likely to be small relative to the entire Valley area, and the overall impact of the settlements and camps is likely to be minimal. If irrigable land is developed then the effects of introduced pesticides would be more widespread."

2.6 AMPHIBIANS AND REPTILES

2.6.1 Amphibians and Reptiles of the Valley

Little work has been done on these animal groups in the Valley, but it is believed that no species are restricted to the Zambezi alluvial system, although the amphibians tend to concentrate here (D. Blake, Dept. of National Parks and Wildlife Management; pers. comm.). The middle-Zambezi is an ideal habitat for Nile Crocodiles and in view of the abundance

of these reptiles here the operators of crocodile farms at Kariba are permitted to collect eggs in the Valley. Crocodiles breed mostly on the sandbanks in the river, in the period September-December.

2.6.2 Impacts of the Mupata Scheme on Amphibians and Reptiles

In the short-term, the impacts of the Mupata scheme on most reptiles and amphibians will certainly be adverse, although no species is likely to be made extinct. Once beds of reeds and rushes developed along the shoreline, the amphibians should recover from the loss of the alluvial system, as at Lake Kariba. Crocodile populations would suffer due to the loss of breeding area, but in time sub-optimum breeding sites would be found in the sandy (jesse) areas along the shoreline, and sandbars might develop at the mouths of the incoming seasonal rivers. Until the breeding did stabilize, some of the Kariba crocodile farmers could have difficulty in obtaining eggs to maintain their production. Crocodiles eat a wide diversity of food, ranging from the insects that they eat when they are young to the large mammals that they are able to tackle when they are older, and fish are always a major component of their diet. A good diversity, and quantity, of food should be available in the new lake, especially in the shallow, weedy estuaries.

2.7 ORNITHOLOGY

(Information derived largely from the contribution of Tree, 1981)

2.7.1 Bird Populations of the Valley

Little ornithological work has been done in the Zambezi valley apart from a few checklists (e.g. Cooper, 1972; Haxen, 1981; Smith, 1950). Members of the Zimbabwe Schools Exploration Society carried out brief investigations into the different bird habitats around the Sapi/Zambezi confluence in August, 1981.

With its diversity of vegetation types and lack of human pressure, the Valley is richly endowed with bird species, and is especially noted for its large population of raptors.

The sandbanks in the Zambezi River, the flood-channels, the river-cut cliffs, the pans, the riparian plant associations and other geomorphological and botanical features of the Valley provide unique feeding and breeding opportunities for birds. The importance of the riverine area along the Zambezi as a staging post for migratory birds may be considerable. Among the many palearctic migrants that stop-over here during summer are the Curlew Sandpiper (Calidris ferruginea), the Little Stint (Calidris minuta), the Greenshank (Tringa nebularia), the Ringed Plover (Charadrius hiaticula), the Green Sandpiper (Tringa ochropus) and the Marsh Sandpiper (Tringa stagnatilis). As with the mammals, the riparian plant associations are utilized by many birds in the dry season, when the habitats away from the main rivers are no longer hospitable. On the alluvial terraces along the Zambezi, it appears that the diversity of bird species is correlated with the diversity of plant species in the different riparian associations, as would be expected. On the lower deposits, with a very strong dominance of Acacia albida over other woody species such as Kigelia africana and Diospyros senensis, fewer bird species are found than on the higher deposits where the vegetation is more mixed, with increased proportions of trees such as Combretum imberbe, Cordyla africana and Lonchocarpus capassa as opposed to A. albida (although the latter may still be dominant). Similarly, the mopane woodland, with its limited plant species diversity, may not support as rich a bird community as could the more diverse jesse thicket outside the dry season.

2.7.2 Impacts of Lake Mupata on Birds

Important bird habitats that would be inundated by Lake Mupata would be the sand- and pebble-banks in the Zambezi River and the alluvial deposits (with the A. albida woodlands and flood-channels).

The shifting sand-banks provide isolated habitats that are seasonally submerged and are therefore largely unvegetated, and are free of most of the land predators. The Skimmer (Rynchops flavirostris) and the White-fronted Sandplover (Charadrius marginatus) are totally dependent on these sand-

banks for breeding. With inundation, the Zimbabwean population of Skimmers will decline drastically; the few pairs found upstream of the Victoria Falls and possibly on the lower reaches of the Lundi River may not be sufficient for long-term conservation of this species in Zimbabwe. Small populations of White-fronted Sandplovers are also found on the Sabi/Lundi and Limpopo river systems, and the plight of this species would be less serious. The White-crowned Plover (Vanellus albiceps) also breeds on sandbanks, but is seems from the situation at Kariba that this species could adapt to a lakeshore environment, albeit in much reduced densities. Furthermore, the White-crowned Plover is widespread on larger sand rivers of the Lowveld and Middleveld. Another sandbank breeder, the Water Dikkop (Burhinus vermiculatus) could also adapt to the changed circumstances, and is common in Zimbabwe. The breeding population of the Stilt (Himantopus himantopus) is very small in Zimbabwe and is confined mainly to the Zambezi River, in isolated pairs; again, this species could probably still find some breeding sites along the shoreline of Lake Mupata. The Three-banded Sandplover (Chradrius tricollaris) seems to prefer muddy deposits on which to search for food, and the Zambezi habitats at present are probably sub-optimum for them. They are common throughout Zimbabwe and would readily adapt to the new shoreline.

Red-winged Pratincoles (Glareola pratincola) breed in small colonies on pebble banks, mainly on the Zambezi system in Zimbabwe, but may still find isolated homes after the inundation, as at Kariba. Their relatives, the White-collared Pratincoles (Glareola nuchalis), are dependent on rocky outcrops, in stretches of rapids, on which to breed (such as in Mupata Gorge), and would not adapt to a lakeshore environment. Much suitable habitat was submerged under Lake Kariba, and apart from a small population near Victoria Falls, the remaining Zimbabwean representatives of this species are found on the Zambezi below Kariba.

Most of the bird species found on the alluvial terraces are widespread in Zimbabwe, hence the loss of these areas would result in only a slight reduction in the overall populations of such species. However, some birds appear to be particu-

larly dependent on the riparian vegetation. The Long-tailed Glossy Starling (Lamprotornis mevesii), a Lowveld bird found in both the north and south of Zimbabwe, concentrates in riparian woodland during the winter months, and our northern population would decline considerably with the loss of this type of habitat. The Purple-banded Sunbird (Cinnyris bifasciatus) migrates from higher levels to the Zambezi Valley and Mocambique for winter, so the Zimbabwean population utilizing the Zambezi riparian woodlands would be adversely affected, unless the birds could adapt to a longer migration into Mocambique. The relatively scarce Nyasa Lovebird (Agopornis lilianae) is another local migrant, moving from the mopane into the Acacia woodland in summer. The Nicator (Nicator gularis) is also a fairly scarce bird in this country, and preservation of the riparian woodland along the middle-Zambezi may be essential for its long-term survival in Zimbabwe. This is also the case with Livingstone's Flycatcher (Erythrocercus livingstonei), whose plight is even more desperate; most of the Zimbabwean population is concentrated along the Zambezi downstream of Kariba.

Several larger species of birds such as raptors, storks and ibises depend on the riparian woodland for nesting sites, ranging away at non-breeding times. The Martial Eagle (Polemaetus bellicosus) and the Bateleur (Terathopius ecaudatus) are examples; their populations have declined severely in recent years in Zimbabwe. The Banded Snake Eagle (Circaetus cinerascens) is rare in this country, occurring mainly along the middle-Zambezi, hence inundation of this sector would decimate Zimbabwe's small population (the status of this species in neighbouring countries is apparently healthier). The Zambezi riparian woodlands may support the highest density of Brown Snake Eagles (Circatus cinereus) in Zimbabwe; a density of one pair per kilometre was recorded in the area of Matawatawa Pool (Sapi Safari Area) in August, 1981.

The flood-channels and pans of the alluvial system are utilized by a variety of water-birds. The Zimbabwean population of the Rufous-bellied Heron (Ardeola rufiventris) is confined almost entirely to such habitats along the Zambezi River between Chirundu and the Chewore mouth, and would not be maintained

with a lakeshore environment. Similarly, most of the remaining Zambezi population of the Hadeda (Bostrychia hagedash) would disappear; Hadedas do not appear to have survived at Lake Kariba. The Egyptian Goose (Alopochen aegyptiacus), although widespread and numerous, maintains its highest densities in Zimbabwe on the middle-Zambezi; numbers on Kariba are low. The Pygmy Goose (Nettapus auritus), which is declining seriously in Zimbabwe, depends on quiet waters in riparian woodland for breeding, so a potentially significant breeding area would be lost. The middle-Zambezi is also an important breeding area for the Saddlebill Stork (Ephippiorhynchus senegalensis). This species has adapted to Kariba's shoreline, although densities are likely to have dropped considerably from pre-impoundment levels.

River-cut cliffs along the Zambezi and a few of its tributaries are important for some hole-nesting birds, including bee-eaters, kingfishers, martins and a swift. Several large colonies of the Carmine Bee-eater (Merops nubicus) are found along the Zambezi in clean-cut alluvial banks of 5 m or more in height, as well as smaller colonies of the White-fronted Bee-eater (Merops bullockoides) in the same habitat. The African Sand Martins (Riparis paludicola) appear to prefer less-consolidated banks of 2-3 m in height. An important breeding zone for these fairly uncommon and beautiful birds would be inundated, although some cliffs would still remain on the tributaries (there is at least one Carmine Bee-eater colony on the Rukomechi River, for instance, just downstream of the Tsetse Research Station).

Kenmuir (1978) reports a few cases of bird species that have prospered on Lake Kariba, and these birds should therefore also benefit from the creation of Lake Mupata. The Fish Eagles (Haliaeetus vocifer) are probably the best-known birds on Lake Kariba; they may be more numerous than they were on the flooded section of the Zambezi. The White-winged Black Terns (Chlidonias leucoptera) appear to have changed their feeding behaviour in order to utilize the stocks of freshwater sardine. They now dive for these sardines, whereas their previous behaviour was to hawk for insects over the surface of the river or its banks. The Reed Cormorant (Phalacrocorax

africanus), the Darter (Anhinga melanogaster) and the Pied Kingfisher (Ceryle rudis) have also thrived in the lacustrine environment (Jarman, 1968).

Overall, it appears that the great majority of birds presently utilizing the middle-Zambezi (either seasonally or permanently) would be adversely affected through the creation of Lake Mupata; a few species might eventually disappear, or at least decline drastically, in this country due to the loss of breeding habitats.

2.8 MAMMALS

2.8.1 Mammal Populations of the Valley

(Information on primary productivity derived from the contribution of Dunham, 1982)

Since the Valley consists almost entirely of land set aside and carefully managed for wildlife conservation it has healthy populations of many wild mammal species. An aerial survey carried out by the Department of National Parks and Wildlife Management in August, 1980, enabled rough estimates to be made of some of the large mammal populations. For an area of 7 770 km^2, which included portions of the Urungwe Safari Area, the Mana Pools National Park, the Sapi Safari Area, the Chewore Safari Area and the Zambian Lower Zambezi National Park, lying between the escarpments, the estimates of total Elephant and Buffalo populations were 8 100 and 18 000 respectively. There are probably at least 200 Black Rhinoceros in the Chewore Safari Area alone. Notably missing from the Valley are Wildebeest, Giraffe and White Rhinoceros. Very little information is available on the small mammals of the Valley.

A major feature of the ecology of the Valley is a seasonal migration of various species of large mammals in response to food availability; the Zambezi alluvial system constitutes a dry season concentration area for these species. This is due to the fact that plant productivity is greater and more prolonged, and shade and water in the late dry season more abundantly available in this area than on the rest of the Valley floor and Escarpment (Jarman, 1972). Once soil

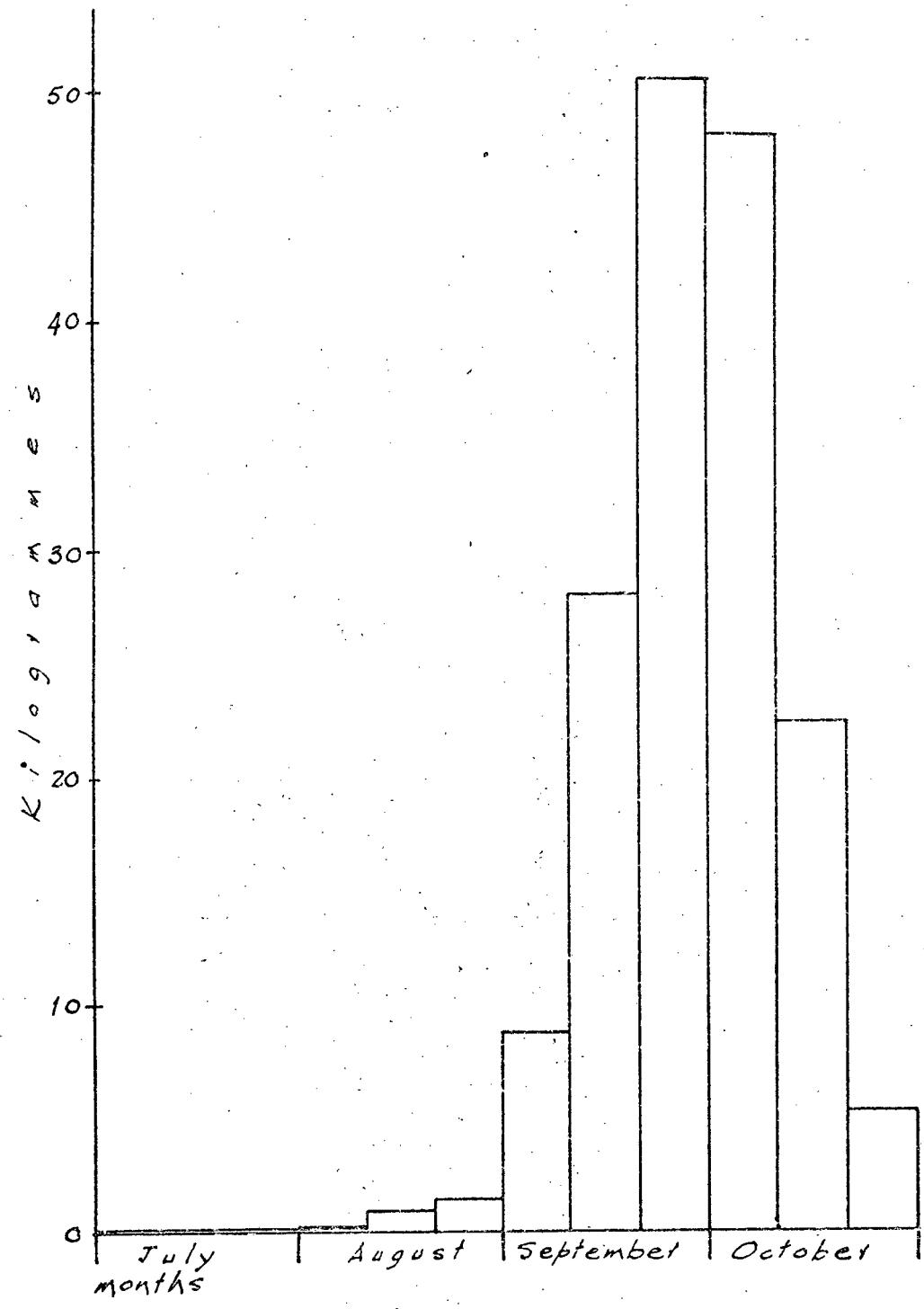
moisture diminishes in the mopane and jesse soils at the end of the wet season, the productivity first of grasses and then of browse plants declines and so the grazing mammals (such as Zebra, Buffalo and Impala) move down the catena to moister alluvial soils, followed by the browsers. Some browsers, such as Kudu, Eland and Black Rhinoceros, do not show such obvious migrational behaviour since they are able to find adequate food off the alluvial system throughout the year, and may move towards the Zambezi River only because of the attractions of shade and water. In the southern and eastern parts of the Valley, some large mammals move into the hills, where permanent water supplies are available, and find woody browse and a little grass in the gullies and miombo woodlands.

In the alluvial system, the dominant tree species, Acacia albida, is of particular importance as regards the provision of shade and woody browse. This tree has a "seasonally-inverted" foliage cycle in that it is leafless during the wet season and comes into leaf, and produces fruit, during the dry. The phenomenon is probably due to a variety of physiological factors, possibly related to root-drowning when the water-table rises at the onset of the wet season. In the dry season, the appearance of much of the alluvial woodland at Mana Pools is that of a parkland between grassed drainage lines, with a canopy provided by the crowns of the A. albida trees (which have a mean density here of about 12 per hectare) and some evergreen trees. There are very few woody species beneath the tree canopy, and with the trampled grass cover, good visibility is afforded to the ungulates, so they are given some ease from predators.

The production of pods by A. albida trees is estimated at about 1 000 kg ha^{-1} yr^{-1} in the Mana Pools area, with September-October as the period of peak production (Fig. 6). This estimate represents those pods that actually fall, and an additional considerable amount of pods is eaten, while they are still unripe, by Chacma Baboons. Once on the ground, the pods are sought by Elephant (mainly bulls), Buffalo, Impala and other mammals. In Tanzania, A. albida pods were found to have a crude protein level of about 13 per cent (Gwynne, 1969).

FIG. 6

ANNUAL PRODUCTION OF PODS BY ONE ACACIA ALBIDA TREE, MANA POOLS



(Dunham, 1982)

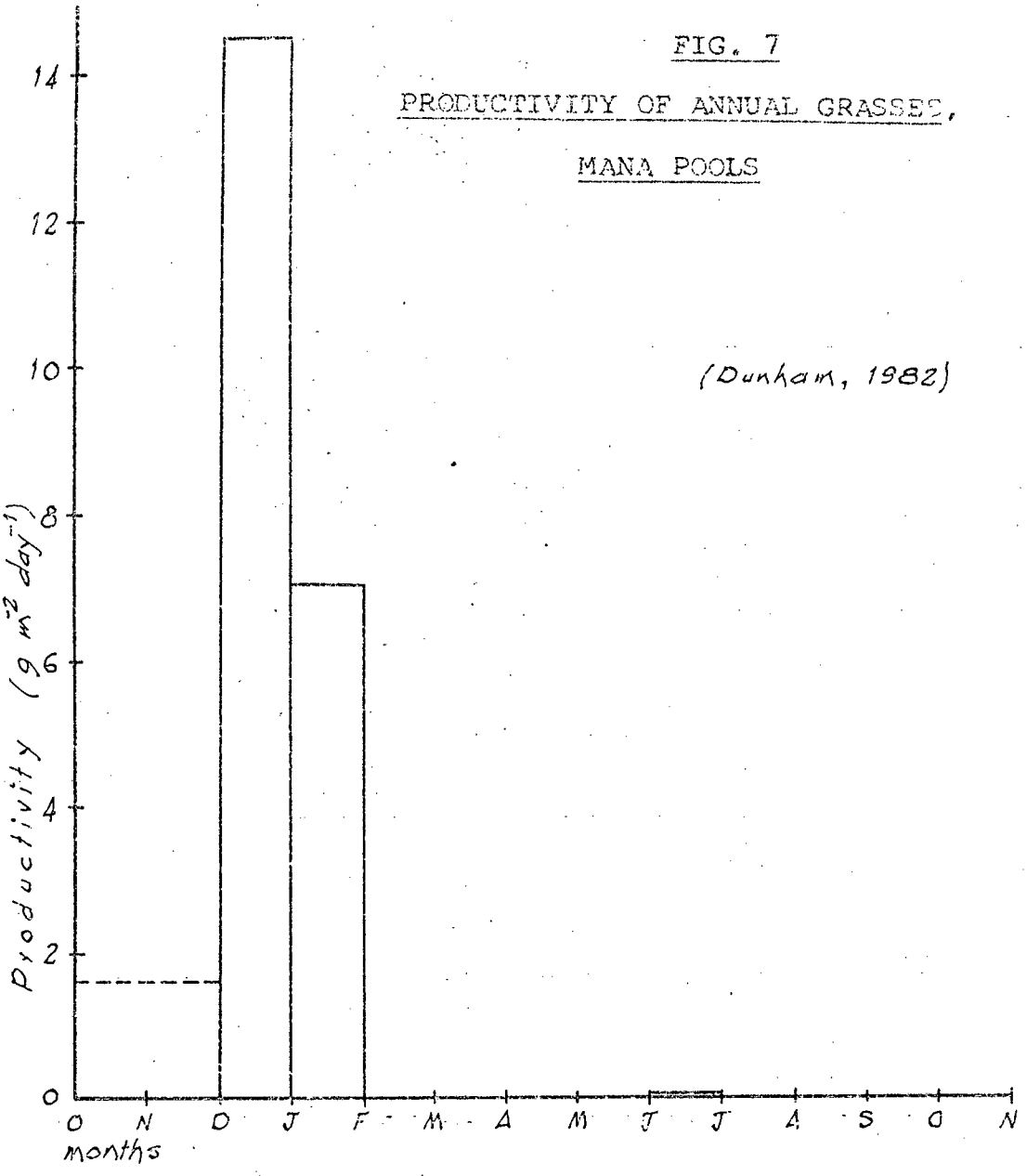
The new foliage of young A. albida saplings, which are pioneer colonizers of recently deposited alluvia, is also heavily browsed by various species since this dry-season greenery is most conspicuous. Even the woody, thorny foliage of the older A. albida trees is ripped off by the Elephant so that a distinct browse line is evident about 7 m above the ground, enhancing the canopied appearance of the woodland. Browse is also provided by broad-leaved evergreen trees such as Trichelia emetica; Elephant generally prefer the denser clumps of these trees to the Acacia woodlands until the pods are produced, and Impala tend to utilize the evergreen browse when the quantity and quality of the grass of the alluvial system diminish in the late dry season (Jarman, 1972).

Grazing animals find some perennial grasses, such as Oryza barthii, Setaria sphacelata and Vetiveria nigritana, growing at the driest time of year on islands in the Zambezi River, and in drainage channels between blocks of alluvial woodlands. The productivity of these perennial grasses has not yet been measured.

With the first moderate shower (as little as 10 mm of rain), growth of annual grasses commences on the alluvial soils. These grasses, such as Panicum maximum, Echinochloa colonum and Urochloa trichopus, have an estimated minimum productivity of 7 470 kg ha^{-1} yr^{-1} and provide good quality food for the grazers at the start of the rainy season. During the second half of the rainy season, the productivity of the annual grasses declines and forbs (i.e. non-woody dicotyledonous plants) reach the peak of their productivity (which is estimated to be at least 3 230 kg ha^{-1} yr^{-1}). As the water-table rises, the large mammals tend to move out of the alluvial system, leaving the new plant growth largely to the invertebrates. For many ungulates, the muddiness of the alluvial soils, the prevalence of parasites and the difficulty of seeing predators in the long grass, make the riverine environment less favourable at this time than the deciduous mopane and jesse communities, where fresh leaves, forbs and annual grasses are available (Jarman, 1972). However, Hippopotami, Vervet Monkeys and many Waterbuck do not move away from the river.

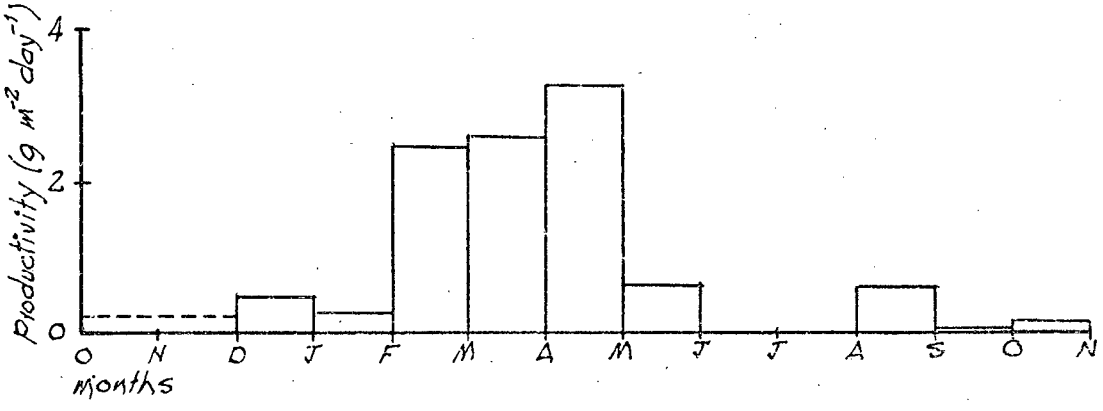
FIG. 7

PRODUCTIVITY OF ANNUAL GRASSES, MANA POOLS



(Dunham, 1982)

FIG. 8 PRODUCTIVITY OF FORBS, MANA POOLS



(Dunham, 1982)

TABLE 6

HERBIVORE FOOD PREFERENCES AND USE OF THE ALLUVIAL SYSTEM (Jarman, 1972)

SPECIES	FOOD PREFERENCES	USE OF ALLUVIAL SYSTEM
Hippopotamus	Grass	All animals, all year.
Waterbuck	Grass	Breeding population all year, all animals for late dry season.
Warthog	Grass, grass roots	All animals from mid dry season to start of rains.
Zebra	Fresh grass, little browse	All animals from mid dry season to start of rains.
Impala	Fresh grass and browse	Few early, but all by late dry season.
Elephant	Browse and (long) grass	Increasing from mid to late dry season.
Buffalo	Grass, some browse	Late dry season.
Sable	Grass, some browse	Late dry season.
Eland	Browse, some grass	Partial use late dry season.
Kudu	Browse, little grass	Partial use late dry season.
Black Rhinoceros	Browse only	Not used for feeding; for water late dry season.

The primary productivity of the non-alluvial deciduous communities (mainly mopane and jesse) fluctuates from year to year due to the very variable annual rainfall. While this food is available, the large mammals find water at numerous pans scattered throughout the flatter areas of mopane woodland, and Elephant are able to dig waterholes in the sandy beds of the larger rivers. The seasonal migrations up and down the catena, and the different habitat preferences shown by the various age/sex groups of particular species (such as Elephant and Impala), help to ensure that maximum benefit is derived by the mammals from the food supplies of the Valley as a whole; the limited productivity of the mopane, jesse and other non-alluvial communities is fully utilized, and the vegetation of the alluvial system is given a chance to grow during the rains.

Mammal numbers have evidently risen since the Valley was given conservation status over twenty years ago; particularly notable population increases have been shown by Zebra, Impala, Buffalo, Chacma Baboons and Elephant (Hughes, undated). The tribespeople who previously inhabited the Valley kept mammal populations down through hunting and through degredation of habitats (by cultivation and burning each year). The availability of ivory in the Valley declined considerably towards the end of the last century, so that Portuguese traders were no longer able to operate profitably (Selous, 1881); prior to the late 1920's there were very few resident herds of Elephant between the Mana Pools/Rukomechi area and the Angwa River (Hughes, undated). The expansion of the Elephant population of the Valley has occurred so rapidly that some ecologists feel that there is now a need for culling in order to prevent degradation of the vegetation. Other ecologists argue that the Elephant are merely "modifying" the plant communities rather than "degrading" them and it should not be assumed that the changes are necessarily "undesirable". Whatever the correct attitude might be, the Elephant are quite obviously suppressing the regeneration of some species (particularly A. albida) on the alluvial terraces, are converting some of the jesse communities from dry forests to low thickets through their felling of the taller trees (such as tree Combretums and Commiphora spp.),

and are thinning the miombo woodlands of the Escarpment.

2.8.2 Impacts of the Mupata Scheme on Large Mammals

(Information derived largely from the contributions of Dunham, 1982, Taylor, 1982, and Condy, 1981)

Inundation of the alluvial system of the middle Zambezi would eradicate the present dry-season habitat of many mammals. Although the alluvial communities along the Rukomechi River and in a few other localities, as well as some non-alluvial communities, would still provide dry-season browse for certain ungulates, there would be no substitute (in the short-term, at least) for the open Acacia parkland and vleis along the Zambezi that presently meet the socio-ecological requirements of the grazers in particular. Little is known about the potential carrying capacity of the plant communities that would be above the shoreline, but the indications are that these communities are already fully-utilized (some possibly over-utilized) by large mammals and would therefore not adequately support additional numbers in the dry season. It is most unlikely that any mammal species would decline to extinction in the Valley, but several would suffer severe population declines in the short-term, at least, due to compression of range and/or loss of habitat (Table 7). Numerous other species would be adversely affected in less obvious ways. For several of the large mammals, culling operations rather than rescue operations (of the "Operation Noah" type) would be necessary in order to adjust numbers to the carrying capacity of the remaining land. Due to lack of knowledge, impacts on smaller mammals cannot be predicted.

The populations of a few herbivores would recover somewhat, after their initial declines, due to the eventual establishment of a shoreline grassland. At Matusadona National Park, on the southern side of Lake Kariba, the perennial grass Panicum repens spread along the shoreline about a decade after the construction of Kariba Dam, to provide a valuable dry season food source for grazers such as Elephant, Buffalo, Hippopotami and Waterbuck. P. repens is already present along the Zambezi River at Mana Pools. The biomass that this species might produce along the shoreline of Lake Mupata would depend largely on the extent of the drawdown zone.

TABLE 7

IMPACTS OF THE MUPATA SCHEME ON SOME LARGE MAMMALS

SPECIES	MAJOR IMPACT OF SCHEME	RECOVERY POTENTIAL OF SPECIES
Elephant *Loxodonta africana*	Loss of preferred dry season habitat (especially for bulls) and compression of population. Culling would be necessary.	Population would not recover to pre-impoundment levels.
Hippopotamus *Hippopotamus amphibius*	Loss of food resources. Culling may be necessary.	Numbers will rise eventually with development of shoreline grassland (Kariba populations are only now beginning to expand, over 20 years after impoundment).
Black Rhinoceros *Diceros bicornis*	Would be disturbed by human activities during construction phase. Increased poaching possible.	Uncertain. Recovery potential very sensitive to the nature and extent of future human activities in the area.
Zebra *Equus burchelli*	Loss of dry-season habitat.	Lakeshore densities in Matusadona N.P. are still low, despite development of shoreline grassland.
Buffalo *Syncerus caffer*	Loss of dry-season habitat and compression of population. Culling would be necessary.	Population should recover well with the development of shoreline grassland.
Waterbuck *Kobus ellipsiprymnus*	Loss of habitat.	Population should recover somewhat with development of shoreline grassland.

TABLE 7 (cont.)

Sable *Hippotragus niger*	Loss of dry-season habitat.	Uncertain. Variable lakeshore densities at Kariba.
Impala *Aepyceros melampus*	Loss of dry-season habitat and compression of population. Culling would be necessary.	Population should recover somewhat with development of shoreline grassland.
Cape Pangolin *Manis temmincki*	Loss of habitat.	Population unlikely to recover to pre-impoundment levels due to reduction in suitable substrate for borrowing (jesse soils too sandy and mopane soils too hard) and to reduced availability of termites.
Antbear *Orycteropus afer*	Loss of habitat.	As above
Warthog *Phacochoerus aethiopicus*	Loss of dry-season habitat.	Low densities at Matusadona N.P., possibly due to lack of suitable refuge sites (old antbear holes etc.).
Vervet Monkey *Cercopithecus aethiops*	Loss of habitat.	Population would not recover to pre-impoundment levels.
Chacma Baboon *Papio ursinus*	Loss of preferred habitat.	Baboons are quite adaptable but population could not recover to pre-impoundment levels.

It is believed that the lake-level would be kept as high as possible throughout the year in order to maximize the head of water at the dam wall; however, with the gentle slope along much of the shoreline, even a slight drop in the level of the lake would lead to the exposure of a large area, on which P. repens might grow rapidly. There is a possibility that the growth of P. repens might be complicated by the competing growth of reeds and rushes and by high densities of dead woody plants along the shoreline in jesse areas.

Much of the remaining land around Lake Mupata, especially in the Mana Pools National Park, would be similar to the Matusadona National Park in terms of soil and vegetation, so a comparison of the large mammals in the two areas should indicate the likely effects of dam construction. Unfortunately, the only adequately detailed information on animal densities in the Valley below Kariba is rather old, is restricted to a few times of the year and refers only to the Mana Pools alluvial system; this information was gathered by Jarman(1972) in the mid-1960's. However, it is unlikely that the situation at Mana Pools has changed much. The dry-season densities of some large mammals in the alluvial system (recorded by Jarman in October, 1965), and the recently recorded densities of these species (averaged over the whole year) on the remaining area of valley floor at Matusadona National Park are shown in Table 8 . The total biomass of these animals in the alluvial system in the dry season is in the order of five times that of the average total biomass of the same set of species in the Matusadona National Park valley floor area, which is felt to be representative of the area between Lake Mupata and the Escarpment. The metabolic biomass data are plotted in Fig. 9 (metabolic biomass, i.e. body mass ^{0,75}, is used as a comparative measure of metabolic activity in an ecosystem; this index allows for the fact that smaller homiothermic animals have a higher metabolic rate and therefore a higher food requirement per kilogram than larger animals).

The only species that is able to exist at higher densities on the valley floor at Matusadona National Park is the Buffalo, due to its ability to meet its food requirements from the

TABLE 8

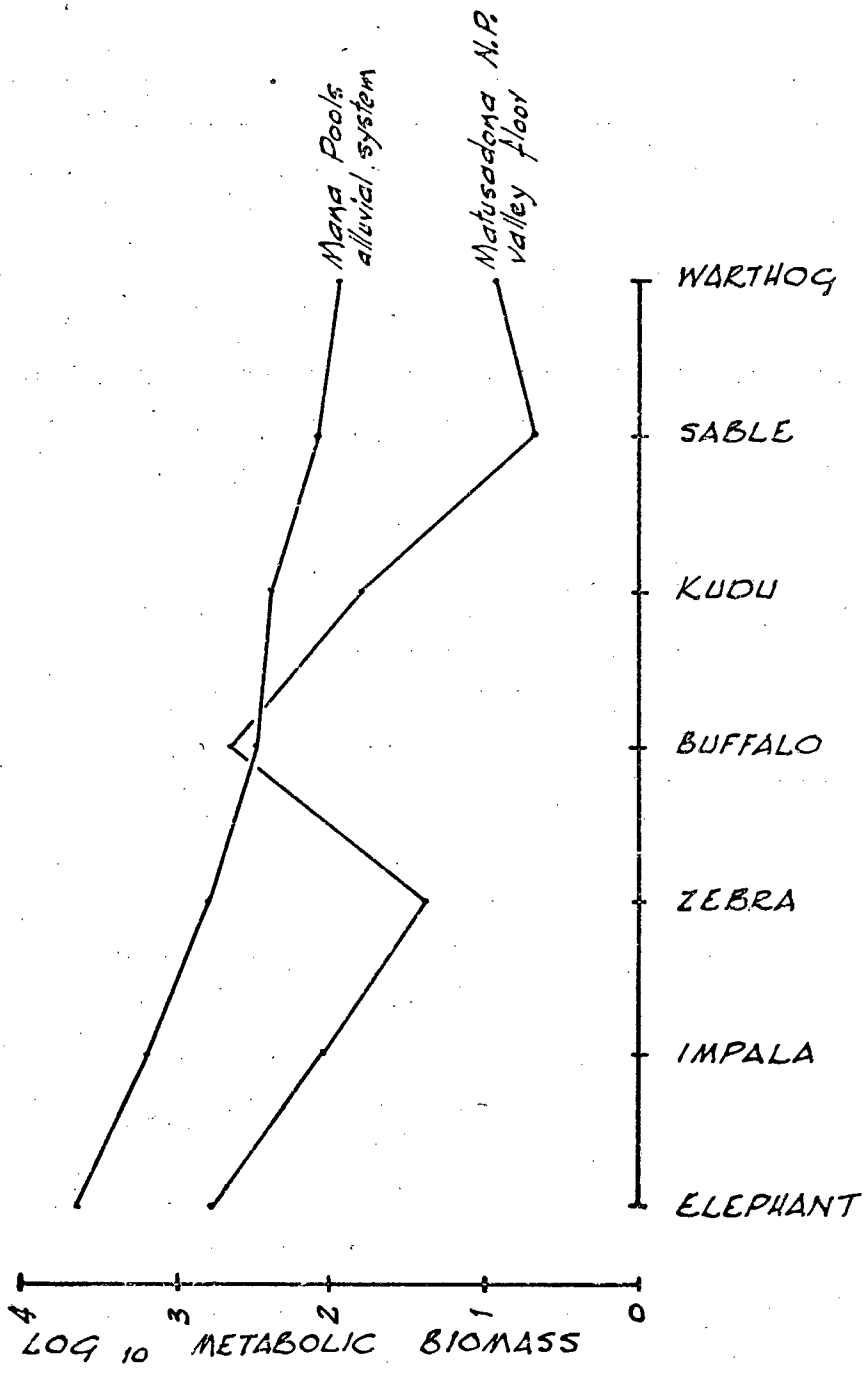
DENSITIES AND BIOMASSES OF LARGE HERBIVORES IN MANA POOLS ALLUVIAL SYSTEM (DRY SEASON) AND ON MATUSADONA N.P. VALLEY FLOOR (ALL YEAR)

(Jarman, 1972; Taylor, 1982)

SPECIES	UNIT WEIGHT (kg)	MANA POOLS ALLUVIAL SYSTEM			MUTUSADONA N.P. VALLEY FLOOR		
		Density (no.km^{-2})	Biomass (kg km^{-2})	Metabolic biomass (kg ^{0,75}km^{-2})	Density (no.km^{-2})	Biomass (kg km^{-2})	Metabolic biomass (kg ^{0,75}km^{-2})
Elephant	1 725	16,5	28 463	4 416	2,3	3 868	616
Impala	40	101,1	4 044	1 608	6,9	276	110
Zebra	200	12,7	2 540	675	0,5	100	26
Buffalo	450	3,3	1 485	322	4,6	2 070	449
Kudu	136	6,0	816	239	1,5	204	61
Warthog	45	5,3	239	92	0,5	23	9
			38 050			6 660	

FIG. 9

DENSITIES AND BIOMASSES OF LARGE HERBIVORES IN MANA POOLS ALLUVIAL SYSTEM (DRY SEASON) AND ON MATUSADONA N.P. VALLEY FLOOR (ALL YEAR)



P. repens grassland along the shoreline of Lake Kariba. The data clearly show the importance of the Mana Pools alluvial system as a dry-season concentration area for herbivores; with the loss of this area, it is probable that animal densities would eventually stabilize at much the same levels as those recorded at Matusadona National Park. It seems likely that the present average densities of herbivore species in the Valley, outside the Mana Pools alluvial system, are greater than they could be without this dry-season concentration area to relieve pressure on the other vegetation communities at critical times of the year. Thus, overall, the effect of the loss of the Mana Pools alluvial system would be totally out of proportion to the area of the Valley that this system comprises.

The A. albida community on the sandy alluvium along the Rukomechi River would come under severe browsing pressure during the dry season, and the scrubby vegetation on either side of this community would become even more degraded. The green fringe of mopane and a few other species that might retain their leaves throughout the year in the soak-zone of the lake would attract herbivores in the dry season, but would probably be quickly decimated by Elephant, as at Lake Kariba (Jarman, 1968). Increased erosion due to trampling by herbivores and their removal of vegetation cover would be likely in some areas, particularly where the topography is undulating. The management of the herbivore populations, through culling, to minimize such adverse secondary impacts would be a difficult task due to the complexity of the little-studied Valley ecosystem and the consequent impossibility of foreseeing all the environmental perturbations that could result from the creation of the lake.

An effect of reducing the availability of good quality dry-season forage would be to render the herbivores more susceptible to various diseases, many of which presently occur in sub-clinical forms. For instance, the following diseases have been confirmed in Zambezi Valley Buffalo : foot-and-mouth disease, adenoviral disease (bovine serotypes 3, 4 and 8), parainfluenza 3, buffalo pox, rift valley fever, E. coli

infections, brucellosis, mange, parasitic gastro-enteritis and coccidiosis. Many of these diseases affect other species of ruminants. Individually, these diseases do not usually cause great problems, but synergistic effects come into play in times of widespread stress. Animals such as Buffalo which would wade into the lake to eat aquatic vegetation would be exposed to trematode infestations such as schistosomiasis, paramphistosomiasis and liver fluke (which have decimated wild ruminants in Lake McIlwaine National Park). Lake Mupata would create something of a barrier between the animal populations on either side, which would reduce the possibility of a disease such as rinderpest (still not eradicated from East and West Africa) from sweeping south into Zimbabwe's wildlife.

2.9 RIVER FLOW

2.9.1 The Flow Regime of the Middle-Zambezi

The total catchment area of the Zambezi River above Mupata Gorge is about 900 000km^2 (Nugent, 1981; Bolton, 1978). The three main sections that together comprise nearly all of this total catchment are:

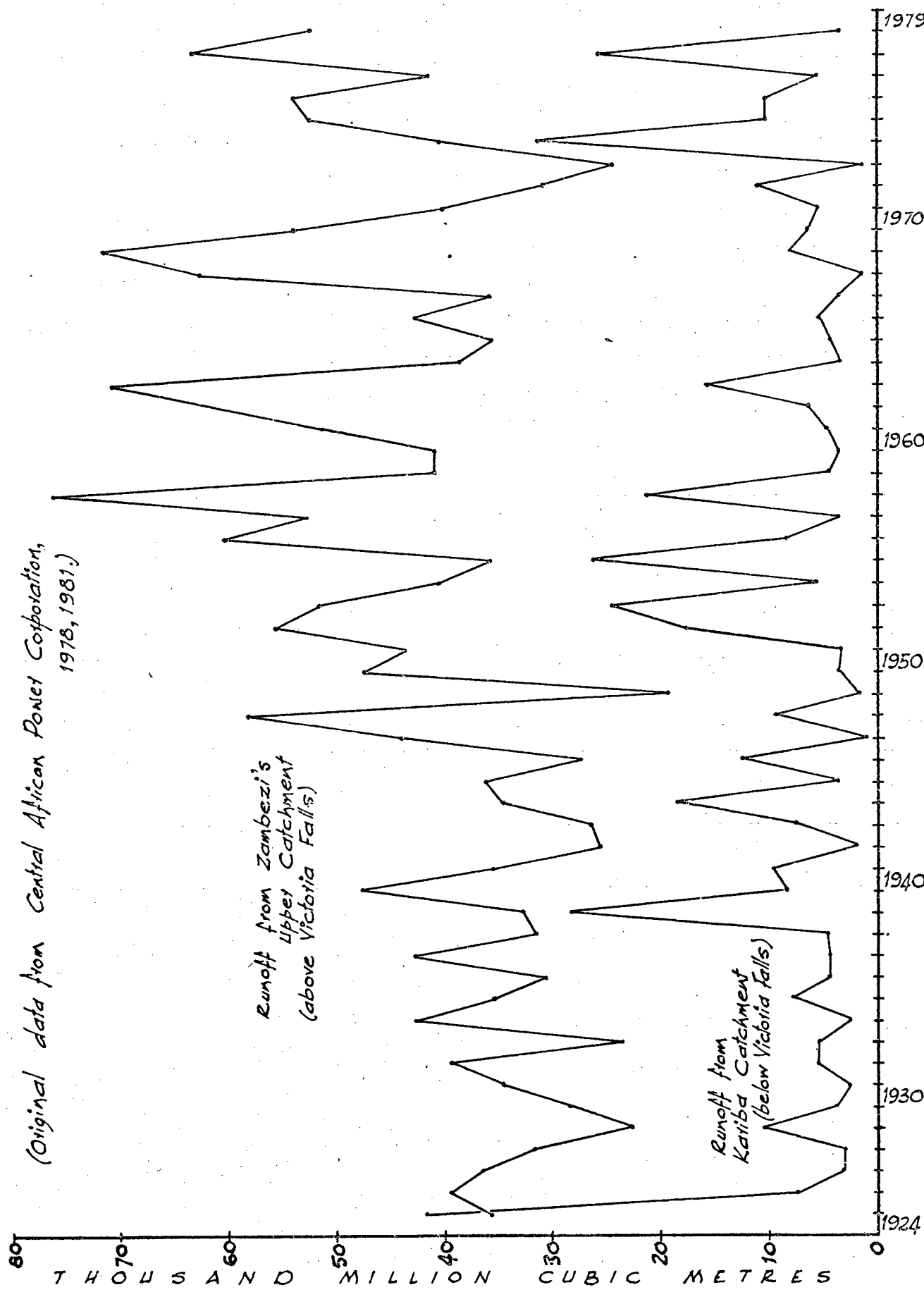
i) the Upper Catchment, for which flow records have been maintained since 1907 at Livingstone Pumphouse, 5 km upstream of the Victoria Falls (the readings prior to 1925 are regarded as unreliable);

ii) the Lower (Kariba) Catchment, feeding in to the stretch of the Zambezi River and Lake Kariba between Victoria Falls and Kariba Dam (estimates of runoff have, until recently, been based on very limited data);

iii) the Kafue Catchment, for which flow records have been kept at Kasaka, just upstream of the Kafue Gorge.

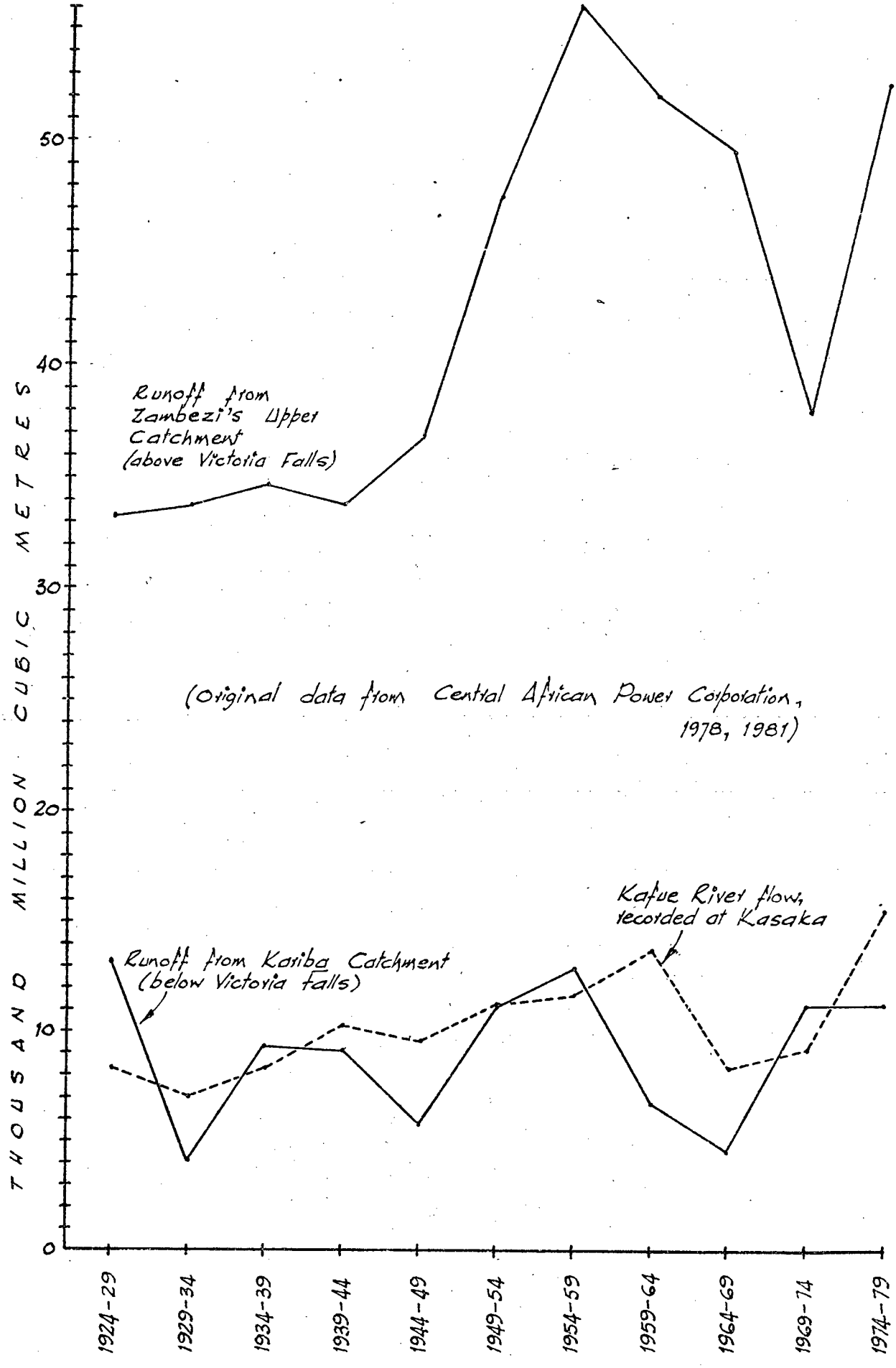
Runoff data for the first two sections have recently been revised by the Ministry of Water Development and by the Central African Power Corporation (1978, 1981) and the data for all three sections have been reviewed by the British Institute of Hydrology (1981). Figures 10 and 11 show the revised information. The major feature of this information is the steep rise in the annual runoff from the Zambezi's Upper Catchment during the late 1940's and early 1950's.

FIG. 10



ANNUAL RUNOFFS FROM 1924/25 TO 1978/79

FIG. 11 MEAN RUNOFFS FOR FIVE-YEAR PERIODS BETWEEN 1924/25 AND 1978/79



By a series of statistical tests, it has been shown that this increased flow is not due solely to increased rainfall, although perhaps 30 per cent of the increase could be explained by this factor (Institute of Hydrology, 1981). Rainfall records for the Zambezi's Upper Catchment are incomplete but using the best of the data available, it appears that the 1950's and 1960's have over 4 per cent more rainfall in most years than the forty-year average from 1930.

Various explanations for the increased river flow have been suggested. The increase might be due to changes in areal distribution of rainfall (higher rainfall in areas with a higher rate of runoff in the later period), or to changes in seasonal distribution of rainfall, or changes in the intensity of rainfall over short time-scales. The latter two possibilities have not been tested, but from annual reports it appears likely that changes in the areal distribution of rainfall have contributed to the anomalous variation in runoff. The possibility of recording errors has been discounted.

Other hypotheses concern changes in the characteristics of the catchment rather than changes in the rainfall. It may be that deforestation and erosion in the upper, high-runoff parts of the catchment have induced greater runoff. Or, it may be that the lower swampy areas of the Barotse Plains and Chobe Swamp have been draining, or have had their inflow channels blocked. There is little evidence to support any of these hypotheses. However, monthly records from Livingstone show that over 75 per cent of the increased flow each year occurs in the five months February to June, and there is little increase during the dry season, so the natural supporting flow into the Zambezi has probably not changed so much as the runoff from the catchment. Also, Fig. 10 indicates that the variations in annual flow from high-flow years to low-flow years have become more pronounced, which might suggest that when substantial rain does fall, it flows off the land very quickly (due to surficial changes), rather than percolating in and maintaining a supporting flow through a following drier year.

The runoff from the Lower Catchment has not shown much long-

term variation, while the runoff from the Kafue Catchment has increased somewhat (Fig. 11). Since the creation of Lake Kariba after impoundment in December 1958, increased evaporation and increased rainfall over the lake have affected the downstream flow. Between 1975/76 and 1979/80, about 7 per cent of the total annual inflow to Lake Kariba consisted of rainfall over the lake, while about 14 per cent of the total annual inflow was lost through evaporation. If the Zambezi's Upper Catchment runoff, the Lower Catchment runoff and the Kafue runoff, each year, are added then an idea is obtained of the Zambezi's potential annual flow in the Valley (Fig.12). This disregards the effects of rainfall and evaporation of Lake Kariba and the Kafue scheme; the net evaporative loss is compensated for to some extent by inflows from tributaries other than the Kafue (which are also disregarded). The filling stage of Kariba is not represented. A general increase in the potential flow each year is apparent, being due to the increased Upper Zambezi and Kafue flows.

Annual and seasonal variations in the flow of the Zambezi are obviously of major significance in terms of both ecology and hydro-electric engineering. Such variations are reflected in the flow records for the Upper Catchment; these show that the mean annual flow is 42,5 x 10^9 m^3 with a minumum of 19,2 x 10^9 m^3 (1948/49) and a maximum of 76,1 x 10^9 m^3 (1957/58). The extreme recorded monthly flows are 23,1 x 10^9 m^3 (March 1958) and 0,37 x 10^9 m^3 (November, 1924), a ratio of 62:1. Consequently, regulation of river flows is an important consideration in any proposals for hydro-electric schemes.

The middle-Zambezi has two high-flood periods each year (see Fig. 13). The first (known to local blacks as Gumbura) comes in about February; this is the lesser of the two, with dirty floodwater, and comes from rainfall in the local region. The second, higher flood (known as Murorwe) used to come (before Kariba Dam's construction) in about April; this brought clean water from the Upper Zambezi Catchment, and apparently lasted only about two weeks. A common belief is that the middle-Zambezi used to flood its banks in many places during the high-flow periods each year, so that low-

FIG. 12

"POTENTIAL" MIDDLE-ZAMBEZI FLOW (UPPER CATCHMENT RUNOFF + KARIBA CATCHMENT RUNOFF + KAFUE CATCHMENT RUNOFF)

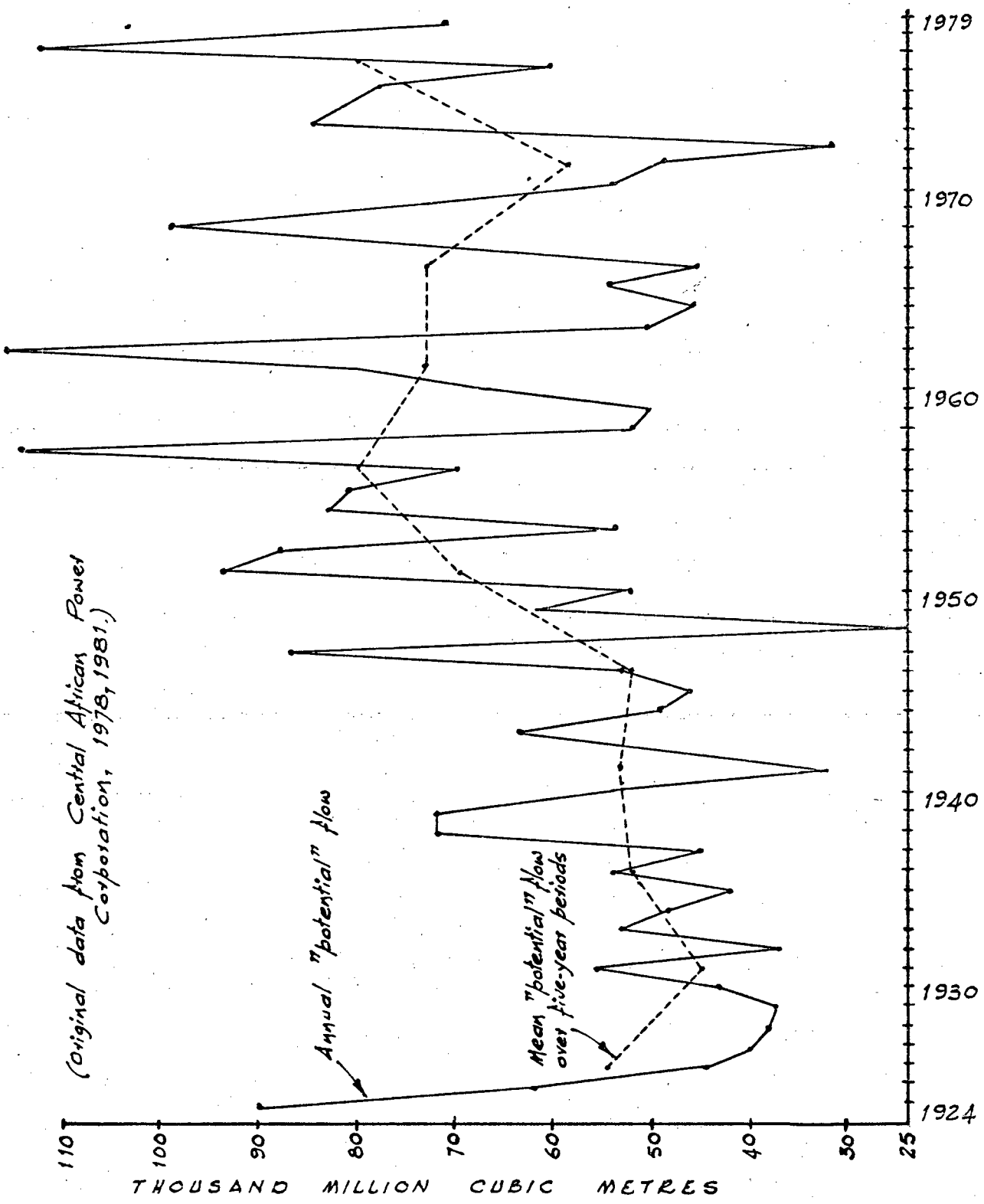
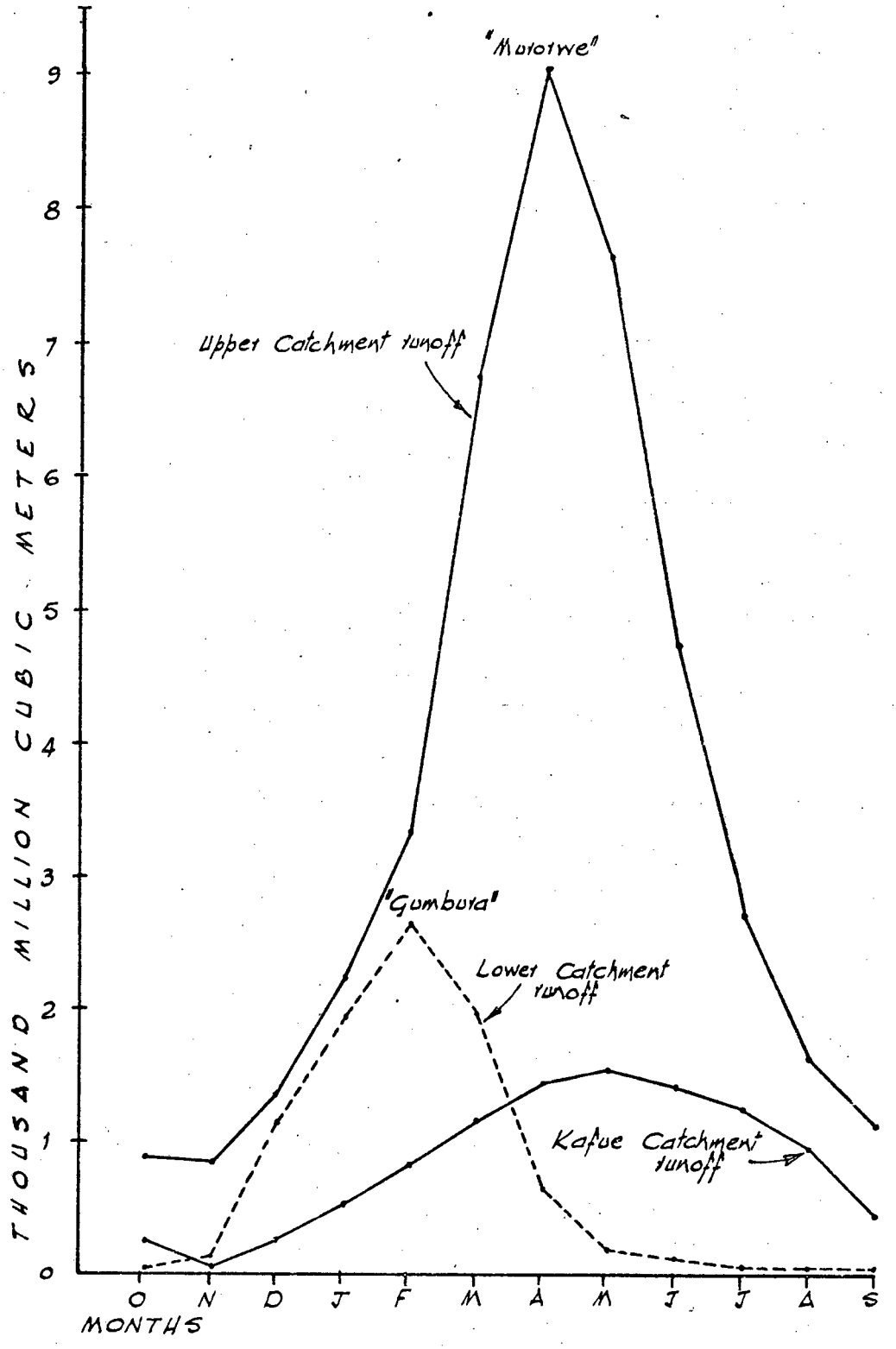


FIG. 13 MEAN MONTHLY FLOWS FOR 55-YEAR PERIOD, 1924-1979

(Original data from: Central African Power Corporation, 1978, 1981; Institute of Hydrology, 1981.)



lying areas such as the "floodplain" at Mana Pools were inundated. This annual flooding is thought to have been important in recharging the fertility of the riverine areas, and the impoundment of the Zambezi at Kariba is regarded as something of an ecological disaster in that the hydro-electric scheme now regulates the river flow. Attwell (1970) states:

> "Formerly, silt loads were brought across the floodplains with the flood, and on gradual recession of the water, regeneration of vegetation occurred with great vigour and in abundance; but since the build-up of the (Kariba) dam, the amount of silt load and the degree of regeneration have decreased." (p. 190)

Conflicting evidence comes from Hughes (undated report), who asked blacks who had formerly lived in the Mana Pools National Park what the flooding regime had been. Hughes wrote:

> "The commonly stated fact that the annual Zambezi floods, prior to the building of Kariba, inundated large areas of the Mana floodplain every season appears to be entirely erroneous according to my four informants. It seems that in the living memory of all four of them (and the eldest must have been well over 80 years old) only three exceptional floods took place, when large areas were under water - and these were as far as can be established in 1916, 1934 and the most recent one was during the construction of Kariba in 1957 ..... 1915 was a poor rainfall year and a small famine was experienced in the area. However, 1916's rainy season proved exceptional and the Zambezi rose to its highest level in living memory and overflowed its banks driving the relatively few families resident on the floodplain to abandon their homes and crops and move up into the mopane and jesse areas to the south. Apparently what is now the Zebra Vlei area was completely inundated with water .. ... In 1924 poor rains were again experienced throughout the country and this year is remembered by all as the year of the great famine .....(In 1938) when Chirundu Bridge was being built over the Zambezi, the river again flooded, but less severely than in 1916,

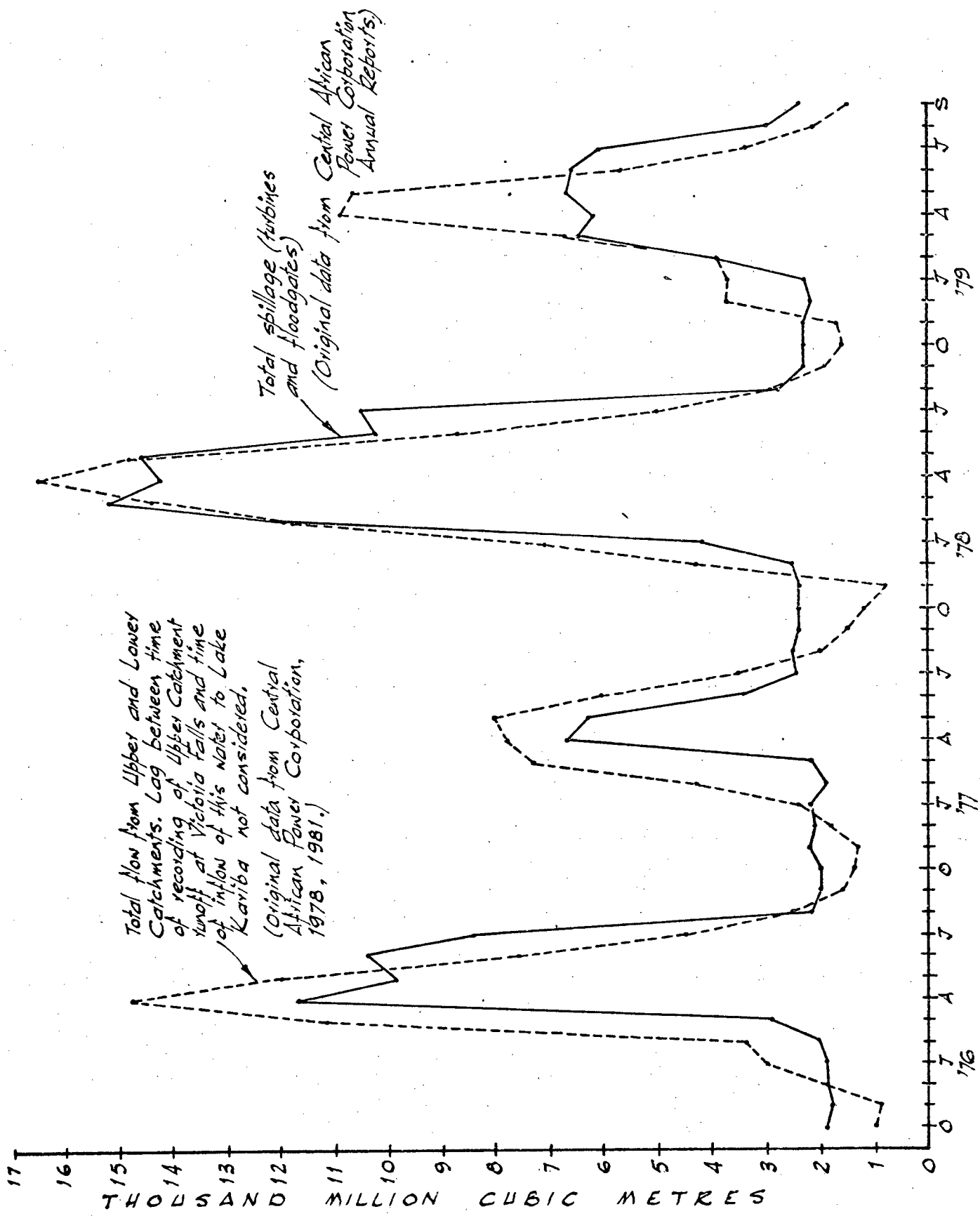
> and all the people living on Nyamombe Island had to be evacuated and those living on the river banks moved up onto higher ground. This minor flood ties in with information gathered from the Chewore area that it was during this year, due to heavy rainfall, that the Chigusa River cut a new route through to its junction with the Chewore. As everyone knows, the big floods of 1957 interrupted the building of Kariba and the flood plain was again subject to severe flooding that year."

The alleged drought in 1924 is not substantiated by the data on annual flows (Fig. 12), possibly due to the old blacks having an incorrect chronology. The high flood in 1938 is reflected in the Lower Catchment runoff record. It should be pointed out that the river flow may vary considerably through a particular rainy season and late rains, or floods lasting only a few days or weeks, will not be reflected in the records for total annual flow.

Apart from the question of the extent of flooding prior to the construction of Kariba Dam, another confusing aspect is that of the manner in which the Kariba Scheme has affected the flow regime of the Zambezi. Attwell (1970) reports that during the first eleven years after the impoundment at Kariba, the Zambezi's floodwater was prevented from reaching the "floodplains" at natural seasonal peak times. Instead, water was stored and released in the dry seasons in volumes greater than the mean dry-season flow of the pre-impoundment era i.e. the river flow was strictly regulated.
Guy(1981) concluded the exact opposite after an analysis of the inflow and outflow records for Lake Kariba between 1966 and 1978 : he felt that the effect of the scheme was to make the seasonal differences in flow more pronounced. Thus, in general, the wet seasons became "wetter" (more water than flowed in was released during the rains) and the dry seasons became "drier" (less water than flowed in was released during the dry seasons).

Fig. 14 represents the situation in recent years (1975 to 1979); monthly inflows and monthly outflows for Lake Kariba

FIG. 14 KARIBA'S MONTHLY INFLOW AND SPILLAGE FROM OCTOBER 1976 TO SEPTEMBER 1979



are plotted. The graph reveals that over this period the Kariba scheme does not seem to have regulated the flow of the Zambezi, on a monthly scale, to a great extent. The inflow was certainly somewhat greater than the outflow during the first part of each rainy season, and the outflow was somewhat greater than the inflow during the dry season, but the outflow was not at all constant throughout each year (as it should have been if the Zambezi were "regulated"); the monthly downstream flow regime was much the same as it would have been without Kariba Dam. This must be qualified by stating that the Kariba scheme has probably regulated the river flow within each month i.e. peak floods lasting only a few days, that might have swept down the Zambezi prior to the dam's construction, are now absorbed within Lake Kariba; such floods may have been very important in the river ecology.

The Central African Power Corporation (CAPCO) forecasts the inflows to Lake Kariba from rainfall records from different parts of the catchment area and from readings of the river-level recorded automatically at various telemetry stations. In the control of the lake-level (through spillage via floodgates), a balance has to be struck between the need to maintain sufficient water to supply the scheme should a series of drought years be experienced and the need to have a safe capacity at the beginning of the rains to absorb unexpected floods, so that the wall is not over-topped. From the power-generating aspect it is more economical to open one gate for three months than three gates for one month, for instance. The tailwater level rises about 5 m with the opening of one floodgate, and thereafter about 3 m with every additional gate that is opened, with a consequent reduction in the head for electricity generation. Thus CAPCO prefers to continue spilling from one or two floodgates for about three months after the inflow has peaked in March/April, rather than releasing excess water rapidly by opening more floodgates. The outflow via the turbines is fairly constant so CAPCO can calculate when to stop spilling from the floodgate(s) in order to have the lake at its safe maximum level at the beginning of the rains.

With the proposed extensions to both the North and South Banks at Kariba (four additional turbines in total) there would be a greater need to keep the lake-level as high as possible throughout the year in order to sustain flow past the turbines, with adequate head. This would mean that the lake would have a reduced ability to absorb sudden floods from the local catchment, so if these were anticipated (and little notice would be possible) then water would have to be spilled quickly via the floodgates. Thus, during the wet seasons the outflows, via floodgates plus turbines, might match the inflow regime more closely (although the total wet-season outflow would be less than the total wet-season inflow), but in the dry seasons the outflows, via turbines only, would probably be more in excess of inflows than at present.

2.9.2 Impacts of the Mupata Scheme on River Flow

The Mupata scheme would be operated basically as a run-of-river scheme i.e. the outflow regime would be very similar to the inflow regime. However, greater use may be made of the regulatory potential of the Kariba scheme in order to stabilize the lake-level of Mupata at as high an elevation as possible, so that maximum head is always available at the relatively low dam. The altered pattern of inflows to Lake Mupata would then lead, with the run-of-river mode of operation, to an altered pattern of flows downstream of the Mupata Gorge.

Downstream flows would also be affected by evaporative losses from Lake Mupata. The power engineers have assessed the evaporative loss from Lake Mupata on the basis of the evaporation figures from Lake Kariba, making the assumption that climatic variations between Victoria Falls and the Mocambique border are relatively minor. Mean open-water evaporation at Lake Kariba is 1563 mm per year, and average rainfall is 821 mm, giving a mean net evaporation of 742 mm per year (Merz and McLellan, 1981). Torrance (Dept. of Meteorological Services; pers. comm.) indicated that the evaporation from Lake Mupata may be more than that from Lake Kariba. Taking into account possible climatic changes due to the new water-body (see 2.1.2), he calculated that evaporation

from the lake near Chirundu would be about 1800 mm per year. The mean annual rainfall at Chirundu is 628 mm, so assuming that this would be increased by 30 per cent due to Lake Mupata, the net annual evaporation would be about 980 mm. Assuming the same mean net evaporation for Lake Mupata as occurs at Lake Kariba, the total volume lost each year would be about $0,9 \times 10^9$ m^3, which is about 1,5 per cent of the total inflow. If the net annual evaporation is, in fact, nearer 980 mm, then the total loss each year would still be in the order of $1,0 \times 10^9$ m^3. The power engineers do not think that a significant reduction in electricity output at Cabora Bassa Dam would occur due to an annual evaporative loss of this magnitude from Lake Mupata. However, the loss of water due to evapotranspiration from the extensive mats of floating weeds that are likely to develop on Lake Mupata should also be considered; Eichhornia crassipes mats have been shown to increase water loss from the surfaces of water-bodies in arid regions by as much as 7,8 times (Magadza and Fair, 1981).

Merz and McLellan (1981) state:

> "In order to fill the (Mupata) reservoir to the level required to generate power it would be necessary to impound about 12×10^9 m^3. This volume represents about three months' inflow under the normal flow conditions that are likely to prevail during the impounding period ..... It is not expected that compensation flows would be required during this period, at least with the presently installed capacity at Cabora Bassa. Contributions from the Luangwa River and other downstream tributaries together with its own reservoir volume should satisfy requirements at the Cabora Bassa project." (Vol. 1.2, 5.15)

TABLE 9

PROJECTED RIVER FLOWS IN MUPATA GORGE (x 10^9 m^3)

(Merz and McLellan, 1981)

Annual flows	Minimum	Mean	Maximum
From Upper Catchment		44,3	
From Lower Catchment		8,6	
Inflow to Lake Kariba		52,9	
Net evaporative loss		3,9	
Outflow from Lake Kariba	39,1	49,0	80,3
From Kafue	5,5	10,0	26,7
Total inflow (disregarding other tributaries)	47,3	59,0	100,0
Net evaporative loss	0,9	0,9	0,9
Outflow to Mocambique	46,4	58,1	99,1
Monthly flows			
Outflow from Kariba	2,2	4,1	24,5
From Kafue	0,5	0,8	4,4
Total inflow (disregarding other tributaries)	3,8	4,9	25,8

(Losses due to evapotranspiration from weed mats on Lake Mupata are not considered)

2. 10 LIMNOLOGY

(Information derived largely from the contributions of Magadza and Fair, 1981; and Marshall, 1982)

2.10.1 Physico-Chemical Characteristics of the Middle-Zambezi

The seasonal variations in the river flow are of great importance in the limnology of the middle-Zambezi. The flow at the beginning of the rainy season (December) contains a large proportion of runoff water from the local catchment, and must be chemically far richer than the flow in the dry season when there is no local runoff and tributary inputs are insignificant (apart from the Kafue's flow). Dilution of the nutrients in the middle-Zambezi's water takes place during the high-flow periods when floodgates are open at Kariba Dam; Magadza and Fair (1981) found that the conductivity of the Zambezi water at Mana Pools was 75 μScm^{-1} with one Kariba floodgate open and then rose to 95 μScm^{-1} when this floodgate was closed.

The turbine intakes at Kariba Dam are about 20 m below the normal operating level of the reservoir, so during much of the year water is drawn from the cool, deoxygenated hypolimnion (Balon and Coche, 1974). With the turbulent flow through Kariba Gorge, the water must soon become oxygenated again. The outflowing water, when drawn from beneath the thermocline, contains nutrients that have accumulated during the summer stratification of the lake-water.

The contribution from the Kafue constitutes a fairly large proportion of the middle-Zambezi flow (about 17 per cent). Chemically, this contribution is very important. The conductivity of the water just below Mupata Gorge is somewhat higher than the conductivity recorded in the pre-Kariba Zambezi above the Kafue mouth, and is also greater than the conductivity of the Kariba outflow (Hall, Davies and Valente, 1976). It is probable that the conductivity difference between Kariba and the Zambezi entering Mocambique comes from the Kafue input, which is known to be rich in inorganic nutrients.

The other secondary rivers in the Valley come down in spate

for short periods around December, January and February, forming peak floods superimposed on the base flow of the Zambezi. During the dry season, the tributary flows are insignificant; the beds of rivers such as the Rukomechi, Sapi and Chewore are dry, at least in their lower reaches. Thus, as mentioned, nutrient input is much reduced during the dry season. In the permanent pools adjacent to the main channel of the Zambezi, such as those of Mana Pools, the conductivity levels are relatively high; Magadza and Fair (1981) found levels around 200 μScm^{-1} in June. This high conductivity is probably due to a combination of allochthonous inputs, primarily game excreta, and subsequent concentration through evaporation in the dry season. The contribution of nutrients from these pools when they overflow into the Zambezi in the wet season is not considered significant in view of the dilution that occurs.

Water temperatures at Chirundu vary from around 28° C in December to about 19° C in July (Balon and Coche, 1974). The transparency of the Zambezi is low, especially when local flash floods carry material into the river. The river water is well oxygenated. Hall, Valente and Davies (1977) give details of the physico-chemical status of the Zambezi just above the Luangwa mouth.

TABLE 10

SOME CHEMICAL MEASUREMENTS AT MANA POOLS

(Magadza and Fair, 1981)

	RIVER		POOLS		
	7/6/81	8/6/81	QN 4556	QN 5159	QN 5257
Conductivity (μScm^{-1})	82	95	175	300	185
pH	7,2	9,5	7,85	6,98	7,6
NH_4 (mgl^{-1})	0,018	0,015	0,02	0,02	0,015
NO_3 (mgl^{-1})	0,054	0,023	0,05	0,05	0,04
PO_4 (mgl^{-1})	0,016	0,018	0,02	0,02	0,004
Chlorophyll (μgl^{-1})	1,4	7,3	1,24	7,87	?

2.10.2 The Limnology of Lake Mupata

The water of Lake Mupata would be warm, with maximum temperatures approaching 30° C at the surface. Minimum surface winter temperatures would probably be warmer than at Lake Kariba due to the lower elevation of Lake Mupata and to heat export from the Kariba and Kafue reservoirs (c.f. Waikoto lakes; Magadza, 1979). The thermocline is likely to be in the region of 15 m, in comparison with Lake Kariba's at 20 m and Lake McIlwaine's (near Salisbury) at 10 m. Stratification may be weakly developed due to wind action and the shallowness of the lake, and would break down completely in June - July each year when surface and bottom temperatures equalized. Initially, the hypolimnetic waters would be anoxic, with considerable amounts of hydrogen sulphide generated from decomposing organic material, as in the early stages of Lake Kariba. However, with the relatively short replacement time of the reservoir, it is predicted that in due course the hypolimnion would retain some oxygen all year round.

The incoming waters of the Zambezi and Kafue would have low silt loads. The present secchi transparency of Lake Kariba is about 6 m whereas that of the water at the dam in Kafue Gorge averages 2,16 m (Magadza, in preparation); the lower transparency of the Kafue waters is due to brown humic substances derived from decomposition of the Kafue floodplain vegetation. Thus these substances, rather than silt, are likely to influence the transparency of Lake Mupata, making its depth of visibility somewhat less than that of Lake Kariba. The silica level of Lake Mupata would be expected to be slightly higher than that of Lake Kariba, facilitating the petrification of drowned trees.

With the conductivity value of Lake Kariba (in its most eastern basin) and that of the Kafue Gorge reservoir being 84 μScm^{-1} and 200 μScm^{-1} respectively, the composite Lake Mupata would be expected to have a mean ionic conductivity of about 95 μScm^{-1}. At Lake Cabora Bassa, the conductivity values for the open surface waters were found in its first year to range from 95 to 119 μScm^{-1} (Bond, Coe, Jackson and Rogers, 1978); shallow waters near the lake margins, such as the Musengezi estuary, invariably showed higher conductivity

values than the lake mean. This indicates that the inshore, shallower waters of Lake Mupata would similarly have higher values than the suggested mean. At Lake Kariba, it has been found that the inshore waters become especially productive when the reservoir fills at the end of each dry season due to the release of nutrients from animal droppings and vegetation which are then submerged.

The morphoedaphic index, used to classify lakes, is given by:

$$MEI = \frac{\text{Conductivity } (\mu Scm^{-1})}{\text{Mean depth (m)}}$$

For Lake Mupata, $MEI = \frac{95}{16} = 5,9$

This puts Lake Mupata in the same morphoedaphic class as Lake Kainji (West Africa).

TABLE 11

CHARACTERISTICS OF SOME AFRICAN MAN-MADE LAKES

(Marshall, 1982)

	MUPATA	KARIBA	CABORA BASSA	KAINJI
Area (km^2)	1 230	5 364	2 739	1 270
Volume (10^9 m^3)	19,8	156,5	70,0	14,0
Maximum depth (m)	±60	120	151	60
Mean depth (m)	16	29,2	26	11
Conductivity (μScm^{-1})	95	80	95	73
Morphoedapic index	5,9	2,7	3,6	6,6
Replacement time (years)	0,3	3	1	0,3

Lake Mupata would be expected to attain chemical steady state very rapidly and to remain a warm, monomictic, meso-eutrophic lake. This should encourage the production of large zooplankton and phytoplankton standing crops, especially in open waters where there would be less shading by floating macrophytes. Initial eruptions of Limnocnida could occur, as in the Kafue Gorge reservoir.

It seems likely that the turbine intakes of Mupata Dam would draw water mainly from the hypolimnion (when this developed). Thus the outflow, into the headwaters of Lake Cabora Bassa, would be somewhat deoxygenated, with high nutrient levels and, initially, high hydrogen sulphide levels. Apart from possible adverse biological effects downstream, hydrogen sulphide may cause corrosion problems in the power station, as happened at Kariba.

2.11 AQUATIC VEGETATION

2.11.1 Aquatic Vegetation of the Middle-Zambezi

Rooted macrophytes that have evolved to withstand annual flooding, such as the reed Phragmites mauritianus, are well-established along the middle-Zambezi and are important in stabilizing the river banks and sand bars. Floating macrophytes collect in small inlets along the river bank; these macrophytes include the Kariba Weed (Salvinia molesta) and the Water Hyacinth (Eichhornia crassipes). A great variety of rooted and floating macrophytes grow in the pools adjacent to the main river channel (Magadza and Fair, 1981).

2.11.2 Aquatic Vegetation of Lake Mupata

(Information derived largely from the contributions of Magadza and Fair, 1981, and Marshall, 1982)

The probable lack of much variation in the level of the lake would encourage the growth of submerged aquatic macrophytes in the littoral zone, such as Ceratophyllum spp., Lagarosiphon spp. and Potamogeton spp.. These are abundant in shallow parts of Lake Kariba with a sandy substrate, which would be similar to much of the littoral zone that would develop at Lake Mupata. Stands of emergent macrophytes such as Phragmites mauritianus and Typha latifolia can be expected on the lake margins in places where the wave action is not too strong, such as in estuaries. On Lake Kariba, these plants were able to grow on permanent mats of Salvinia and should similarly grow on weed mats on Lake Mupata. Whether rooted in the ground or in weed mats, the emergent macrophytes would be a severe hindrance to boat access to the shoreline. The submerged macrophytes, and the emergent macrophytes with their bases in the water, would be important in providing protection for small fish as well as a substrate for fish food organisms; they would also be utilized by herbivorous fish such as Tilapia rendalli. Emergent macrophytes, especially the rush Typha, might be grazed by mammals if more palatable food is scarce.

The most important floating macrophyte would be the Water Hyacinth (Eichhornia crassipes). This plant has become dominant on Lake Cabora Bassa, where Salvinia molesta (which

invaded the surface of Lake Kariba) is relatively unimportant (Bond and Roberts, 1978). Although the Water Hyacinth would be likely to pose considerable problems in the early years of the lake (as regards hindrance to navigation, fishing, water-sports etc.) its population size would probably eventually be regulated by ecological factors similar to those which affected Salvinia on Lake Kariba. With Eichhornia crassipes as the dominant floating macrophyte, Salvinia molesta would be of secondary importance with Pistia stratiotes and possibly Azolla nilotica of tertiary importance, and various lesser macrophytes adding diversity to the weed mats.
Factors controlling the floating weeds on Lake Kariba, after their initial explosive growth, include the decline in the nutrient status of the lake, wind and wave action, and, to a lesser extent, grazing by invertebrates (such as the introduced grasshopper Paulinia acuminata). Paulinia has been noted at Mana Pools on mats of young Salvinia, which did not appear to be appreciably affected apart from some leaf perforations. The effectiveness of Paulinia in the control of Salvinia on Lake Kariba is doubtful. On Lake Cabora Bassa, the larvae of a moth (possibly Samea sp.) helped check Salvinia growth (Bond and Roberts, 1978). A weevil, Neochetina eichhorniae, has been released on the Kafue and Hunyani rivers in past attempts at control of Eichhornia. These invertebrates, and others, might attack floating macrophytes on Lake Mupata from an early stage. Although the waves on the open waters of Lake Mupata would be relatively large, the numerous dead, protruding trees in the inshore waters would anchor the weed mats and prevent their dispersion by waves and wind. With present knowledge, the extent of the lake's surface that might consist of tree-anchored weed mats or bands of reeds and rushes can only be guessed at; possibly a third? The Zambian shore would have fewer shallow, dendritic inlets than the Zimbabwean shore and would have winds that would be more on-shore (giving rise to stronger wave action) so the waters here might be less choked than the southern waters. However, the Kafue inlet could become very choked.

With the gentle slope along much of the shoreline of Lake Mupata, even a slight drop in water-level would expose a

considerable area of land on which weed mats would be left stranded, to be killed through dessication or grazing. However, the effectiveness of such a control measure would be reduced due to the fact that game, in utilizing the biomass of the drawdown zone, would leave nutrient-rich excreta that would encourage the re-growth of the macrophytes when the lake-level rose again. Chemical control of the floating macrophytes over the whole lake would not be an economic proposition, but might be worthwhile in certain localities, such as the gorge above the dam wall (the easterly winds would help to keep this section clear, maybe against an influence of the water currents). A floating barrier at the entrance to Mupata Gorge might reduce infestation within the gorge.

Although the floating macrophytes would be a hindrance to human activities on the lake and would increase water loss through transpiration, they should perform several useful ecological roles. They would retain nutrients (released from the soil and organic matter of the flooded area) which would otherwise pass downstream via the turbines and floodgates; this would be of considerable importance in Lake Mupata due to the short replacement time of this reservoir (fast rate of flushing). Stranded weed mats might provide mulch and protection for shoreline grasses (such as Panicum repens) on the sandy beaches exposed to strong wave action. The floating macrophytes could carry many invertebrates (2 800 invertebrates are said to have been recorded in a square metre of stable Salvinia mat on Lake Kariba; Kenmuir, 1978), and their trailing roots would provide shelter for small fish and shrimps. However, the mats would reduce light penetration and thus inhibit the development of submerged plants and the associated bottom-dwelling fauna.

2.12 ICHTHYOLOGY

2.12.1 The Middle-Zambezi Fishery

At present, the fish stocks of the middle-Zambezi are utilized by recreational fishermen from Zimbabwe and by commercial and subsistence fishermen from Zambia. The sport fishery, with the famed Tigerfish (Hydrocynus vittatus) and Vundu (Heterobranchus longifilis), draws numerous "weekend" anglers to the Valley. Chirundu is the main destination for such fishermen but many also travel to Mana Pools to combine their angling with game-viewing. On the Zambian side, angling does not appear to be such a significant tourist activity but commercial and subsistence fishing have become very important since the cessation of border hostilities. In 1980, Zambian fishermen set their nets using dugout canoes; in 1981, motorboats were common on the Zambian waters, possibly indicating the lucrative nature of the fishing industry. The Director of the Zambian Department of Fisheries (pers. comm.) estimates fish extraction by Zambian fishermen operating between Chirundu and Feira to be 750 tonnes per year. This figure is based on fish catches which passed through the Zambian check-points and excludes what might be consumed locally.

Jackson and Rogers (1976) consider the maximum number of fish species permanently associated with the middle-Zambezi to be 38. A greater number of species may be found in the river during the high-flow period, but these additional fishes are unable to survive the fierce competition and predation during the low-flow period and are then confined to permanent upland streams of the system. When the Zambezi floods up its side-channels in low-lying areas, such as at Mana Pools, these waters are utilized for spawning by many species if the flooding coincides with their breeding period (Kenmuir, 1976).

2.12.2 Impacts of the Mupata Scheme on some Fish Populations

According to the proposed programme for the construction of Mupata Dam, the wall would be closed around October-November and the reservoir would then take about three months to fill (Merz and McLellan, 1981). When Cabora Bassa Dam was closed

in December, 1974, the Zambezi's flow was cut to less than 10 per cent of its average flow for at least two months, at a time when it should have been flooding (Davies, 1975). This hydrological perturbation seriously affected the downstream breeding of those fish species which depend on overbank floods for spawning. Lake Cabora Bassa occupies about 250 km of the Zambezi's former course below the Mupata dam site, so the impact on breeding of these fish species during the filling of Lake Mupata would not be significant over this distance. However, disruption of breeding may become evident downstream of Lake Cabora Bassa since this reservoir may not spill either during the period required for Lake Mupata to fill, or for a long time thereafter, depending on the prevailing hydrological conditions. Other biological problems are likely to arise downstream during this period e.g. the reduced nutrient input into Lake Cabora Bassa could affect the fish stocks of this lake. Overall, it must be emphasized that ecological requirements, and not just engineering requirements, should be taken into account before the plans to fill Lake Mupata are finalized; a longer filling period may be desirable. Closure (or partial closure) of Mupata Dam towards the end of the year would be beneficial since the initial phase of filling would coincide with the seasonal migration of non-cichlid fish species into shallow waters for spawning (mentioned above); these fishes include cyprinids, characids and siluroids. In the spreading waters of the new lake, the juveniles of these species would enjoy more freedom from predators and a greater availability of food than was possible in the restricted confines of the old river and would therefore survive in large numbers. The commercially important fishes of the family Cichlidae (bream) should also become abundant. Riverine species such as the labeos (Labeo altivelis and Labeo congoro), the Vundu (Heterobranchus longifilis) and Distichodus spp. (Nkupe and Chessa) would find more favourable conditions than in the deeper Lake Kariba (Marshall, 1982). The Kapenta Sardine (Limnothrissa miodon) would become established as it is known to survive the passage through the Kariba turbines. Its population would increase rapidly during the early, nutrient-rich phase of the lake and a pelagic (open-water) fishery could thus develop soon after the lake's formation.

The muddy-pool habitats of the unusual Lungfish (Protopterus annectens) would be much reduced in the Valley (this species also occurs in the South-east Lowveld). The eels (Anguilla spp.) would find yet another obstacle to their determined upstream migration in the form of Mupata Dam (assuming that they were able to get past Cabora Bassa Dam).

2.12.3 Fishery Potential of Lake Mupata

(Information derived largely from the contribution of Marshall, 1982)

The likely yields of fish from proposed African lakes can be very roughly estimated through a relationship described by Henderson and Welcomme (1974). This is based on the morphoedaphic index (MEI) :

$$\text{Yield (kg ha}^{-1}\text{ yr}^{-1}) = 14{,}3136\ \text{MEI}^{0{,}4681}$$

For Lake Mupata, with an MEI of 5,9 (see 2.10.2), this relationship indicates a potential yield of 32,8 kg $ha^{-1}yr^{-1}$ (contrasting with Lake Kariba's present yield of about 23 kg ha^{-1} yr^{-1}). As at Lake Kariba, both a pelagic (sardine) fishery and an inshore fishery would exist.

The inshore fishery, based on the use of gill-nets to catch fishes such as bream and distichodids, could benefit small-scale fishermen since they would require relatively little capital or training to become established. The Zambian fishermen who already operate on the Zambezi would be in a good position to start exploiting inshore fish stocks, but on the Zimbabwean side a conflict would arise between the requirements of such local fishermen, who would need to operate from villages along the shore, and the conservation requirements in the remaining land under the jurisdiction of the Department of National Parks and Wildlife Management. Also, a marketing facility would have to be set up since the lake would be a long way from the main consumers.
Coke (1968) has shown that the "inshore" fishes of Lake Kariba are limited to water less than 15 m deep, so almost 50 per cent of Lake Mupata would be suitable for such fish. With a possible annual yield of almost 33 kg ha^{-1}, the total potential catch of inshore fishes would thus be in the order

of 2 000 tonnes per year. About 1 000 fishermen could be supported by an inshore fishery of this extent, assuming the same standard of living as that of the average inshore fisherman presently operating at Lake Kariba.

The MEI prediction has proved to be somewhat unreliable for the pelagic fishery at Lake Kariba, and on the basis of experience here it seems that a figure of 25 kg ha^{-1} yr^{-1} over the whole of Lake Mupata can be taken as a conservative expectation for sardine production. This gives an annual yield for the pelagic fishery of 3 100 tonnes, which contrasts with the 1981 yield at Lake Kariba of 11 132 tonnes. Such a fishery, which would require over a million dollars in capital investment and would need efficient administration, could support about 500 employees (extrapolating from the Kariba situation). In view of the shallow water and relatively rough conditions on Lake Mupata, different netting methods to those used at Lake Kariba would be required. Sardine yields from the windy Chalala area on Lake Kariba indicate the influence of rough weather on pelagic fishing; in 1980, the catch per boat per month in this area was 3,8 tonnes, whereas in the calmer eastern basin of Lake Kariba the figure was 6,2 tonnes (Marshall, 1981).

A major problem in the development of the pelagic fishery at Lake Mupata would be that of the flooded vegetation. Damage to nets due to snagging would be excessive unless extensive bush-clearing was carried out prior to impoundment. Before the creation of Lake Kariba, 971 km^2 were bush-cleared at a cost of about Z$3 million; since then, costs of bush-clearing have probably quadrupled so to clear, say, 1 000 km^2 in the Valley at the present time could cost in the order of Z$12 million. This clearing would have to be done fairly shortly before impoundment in order not to have the effectiveness of the operation reduced due to re-growth. Bush-clearing would not be so essential for the gill-net fishery and the best policy in the inshore areas might be to clear lanes so that the nets could be set between bands of dead trees that were retained to provide a substrate for the growth of fish food organisms. Another problem of greater relevance to the sardine fishery would be that of the

floating weeds.

The potential for sport fishing at Lake Mupata would be good, with the Tigerfish and Vundu remaining major attractions. The introduction of the Nile Perch (Lates niloticus) might be worth considering once oxygen levels had risen in the bottom waters. This is a good sport fish, sometimes growing over 100 kg, and when smaller it is easily caught in gill-nets (Hopson, 1972). It is piscivorous so its extraction by gill-nets or lines might be a way of deriving the protein from waters in which sardines are difficult to catch.

Poaching by Zambian fishermen is already a major problem on the middle-Zambezi and threatens to be a matter of concern in the management of the fish stocks of Lake Mupata. The creation of the lake would eradicate some breeding sites for Lake Cabora Bassa's fishes, but adequate breeding sites should be available on other large rivers that flow into Lake Cabora Bassa, such as the Luangwa and Hunyani, and any Mocambican fishery that might develop on this lake is unlikely to be adversely affected.

2.13 HUMAN HEALTH

2.13.1 The Current Health Situation in the Valley

The Zambezi Valley is an unhealthy area, with harsh conditions and a variety of tropical diseases in the populated localities. Most of the human population of the area is on the Zambian side; no information is available on diseases among these people. On the Zimbabwean side, the people living in the Dande communal area survive with hyperendemic malaria, schistosomiasis (bilharzia), some filariasis and malnutrition. After prolonged exposure to malaria and schistosomiasis, older individuals living in the area will have acquired some degree of immunity to these diseases. Medical services in the area are virtually non-existent; the only clinic in the eastern end of the Valley, at Chapoto, was closed during the war but is to be re-staffed. People visiting or working in the Mana Pools National Park and the adjacent safari areas have to take prophylactics in order

not to contract malaria. The Zambezi River, bordering on these areas, is probably free of the parasite causing schistosomiasis, the main sources of infection being inland streams and pans in the communal lands. The situation regarding trypanosomiasis (sleeping sickness) is discussed in 2.13.3.

2.13.2 Impacts of the Mupata Scheme on Human Health

Impacts Related to the Creation of a Large Water-body

It is certain that any development that attracts people to the Valley will lead to health problems. The greater the population density in the Valley, whether permanent or temporary, the greater will be the chances of disease transmission. However, it appears that the disease problems associated with some water-bodies (such as Lake Kariba) have been somewhat exaggerated in the literature; the health threat in the Valley could, in fact, be reduced through early implementation of various preventative measures.

Lake Mupata would be an extensive, shallow reservoir with a gently-sloping shoreline, a high nutrient status, relatively high water temperatures and much aquatic vegetation. These conditions would be ideal for the spread of parasites and vectors associated with water and the easy access afforded to local people and to tourists, for fishing and recreation, would facilitate the transmission of diseases.

Malaria due to the protozoan parasite *Plasmodium falciparum* would be one of the major health problems; malaria remains the most important communicable disease in Zimbabwe although it can easily be prevented through the use of prophylactic drugs and residual insecticides. Waddy (1975) states that *P. falciparum* appears to exist in a variety of immunological strains, so that re-infection can occur indefinitely instead of the surviving individuals acquiring some degree of immunity. However, this does not seem to be the case in Zimbabwe, where untreated children in malarious areas either die or else gain natural protection against later infections. *P. malariae* accounts for about 5 per cent of malarial cases in Zimbabwe, and *P. ovale* may give rise to occasional out-

breaks of the disease; the epidemiology of these types of malaria differs to that of P. falciparum, so different control methods are required. The extent to which P. malariae and P. ovale might cause health problems in the Valley, as opposed to P. falciparum, is unknown but they would certainly be much less likely to occur. In the situation of the Mupata Gorge scheme, the malaria that presently exists in the tribal population of the Dande area could reach epidemic proportions if a large number of unprotected workers was introduced to the dam-site; this would be the so-called "malaria of tropical aggregation of labour". The mosquito Anopheles gambiae (in the strict sense) is a very rare vector in Zimbabwe but has been found occasionally in the Kanyemba area, and might be particularly efficient in spreading such an epidemic. Another populated area in which malaria is probably widespread is the Zambian side of the Valley between the Kariba Gorge and the Lower Zambezi National Park. However, it is believed that the Zambezi River already acts as a barrier to mosquitoes, and the creation of Lake Mupata would certainly ensure that infected mosquitoes could not cross against the prevailing easterly winds.

The main malaria vector, Anopheles arabiensis, is a puddle-breeder and would therefore find very suitable breeding conditions in the small, water-filled holes (such as animal spoor) that would abound along the shores of Lake Mupata. With such a gently-shelving shoreline along most of the length of the lake, it would not help much to dig drainage channels along the shoreline, prior to flooding (as was done when dams were built in the Tennessee Valley of America), for instance), since much waterlogged land would still remain. Another control measure that is used effectively with other hydro-electric schemes is to drop the water-level sharply at appropriate times to strand the larvae of certain mosquito species, but this again would not be a good idea, even if it were possible, since it would probably increase the number of puddles for A. arabiensis to breed in. A. funestus spreads occasional epidemics of malaria in Zimbabwe; this species apparently breeds in slow-moving water rather than puddles and might find suitable conditions in the wet season where rivers flow into the lake.

The most effective measures to control malaria would be the use of residual insecticides in dwellings and the use of prophylactic drugs. Biting of humans by mosquitoes normally takes place at night and therefore indoors; the fed mosquito, heavy and lethargic, settles on a wall to rest and then comes into contact with a residual insecticide. DDT is commonly used to combat mosquitoes in Zimbabwe since it remains effective for two or more years after application, whereas the alternative insecticides (organophosphates) are more expensive and have to be applied every few months, and entail greater risks for the applicators. In a township at Mupata Gorge, it might be possible to use an insecticide other than DDT since the spraying programme would be relatively small-scale and could be carefully supervised. Screens on the windows of dwellings would be helpful in keeping out mosquitoes as well as other nuisance insects. The use of prophylactic drugs makes it possible for people to live in the most malarious areas indefinitely. Chloroquine is used extensively in Zimbabwe both as a prophylactic and a therapeutic drug; it would be sensible to use another prophylactic drug at Lake Mupata (there are various other cheap and equally effective prophylactics) in order to lessen the risk of the malaria parasites acquiring a resistance to our main therapeutic. During the construction of Kariba Dam, only two workers died of malaria, both of them Europeans who failed to take prophylactics and who lived outside the township area (Webster, 1960). Thus the malaria threat should not trouble construction workers, fishermen or tourists who take the appropriate precautions, but would be serious for people who neglect, or are unaware of, these precautions.

Intestinal schistosomiasis, caused by the digenetic trematode fluke Schistosoma mansoni, and to a slightly lesser extent urinary schistosomiasis caused by Schistosoma haematobium, would become important diseases at Lake Mupata. The risk of schistosomiasis to workers on the Kariba dam was considered minimal because of the low prevalence of the disease amongst the indigenous population living on the banks of the Zambezi River (Webster, 1960). However, once the reservoir filled and fishermen built villages on the shores, the water around such populated localities became heavily

infested. Despite control programmes, Ministry of Health parasitologists have found high levels of infection in the lake-shore populations; for example, in 1980 a check on African schoolchildren in one of Kariba's townships revealed that 45 per cent of the boys and 34 per cent of the girls were infected with S. mansoni, while the levels of S. haematobium were 38 per cent and 33 per cent respectively. A similar spread of schistosomiasis occurred at Lake Cabora Bassa, and the situation with Lake Mupata could not be expected to be any different. Initially, the rising waters would inhibit the establishment of the necessary host population of snails, but once the lake-level stabilized and marginal hydrophytes grew, an increase in snails could be expected, and the water near settlements would become heavily infected with the parasites.

In areas where schistosomiasis is prevalent, children are soon infected due to their frequent contact with water, and a high proportion of youths may develop abnormalities such as damaged urinary tracts due to S. haematobium, or large livers due to S. mansoni. However, if the extent of the infection is not excessive, the individual will acquire a degree of immunity that may prevent a later massive infection. As a whole, neither children nor adults suffer a serious impairment of health as a result of schistosomal infections, although massively-infected individuals may die (Jordan, 1975). Non-indigenous people visiting Lake Mupata would be most susceptible to serious infections of schistosomiasis, and naturally an overseas tourist would not like to risk being infected even to a relatively harmless extent.

Control of schistosomiasis has depended largely on measures against the snail intermediate hosts. Snails of the genus Bulinus (Physopsis) are the intermediate hosts of S. haemotobium, while snails of the genus Biomphalaria are the intermediate hosts of S. mansoni. Success in controlling snails with molluscicides in large tropical water bodies has yet to be demonstrated (although this method may work in small reservoirs or bays). Mollusc-eating fish, which have the snail hosts as part of their diet, are numerous e.g. catfish, Synodontis; however, there is as yet no evidence that fish have preyed upon snails in large artificial water-bodies to

such an extent as to significantly reduce the incidence of schistosomiasis among humans (Jackson, 1975). It must be appreciated that the definitive host, man, is responsible for the dissemination of schistosomiasis by contaminating the aquatic environment (with excreta), where he in turn becomes infected. Therefore, if the control of schistosomiasis is attempted, consideration must necessarily be given to the ecology of the human as well as to that of the snail. Containment and abatement of schistosomiasis depend on strict shoreline sanitation, education of the local population and, ideally, minimum contact between man and lake-water.

The succession of plants colonizing the shoreline and surface of a tropical impoundment is closely related to the spread of nuisance insects and disease vectors. Floating weed mats of Eichhornia, Pistia and Salvinia enable snails to be transported from localities where schistosomiasis is prevalent to further localities, where humans can then be infected. As previously mentioned, the largest human population on Lake Mupata would be likely to be on the Zambian side upstream of the Lower Zambezi National Park. With regard to disease transmission, it is fortunate that the prevailing winds here would be quite strong and would be on-shore (easterly). The problem of weed mats carrying snails from this area (where schistosomiasis is likely to be prevalent) to the Zimbabwean shore should be much reduced; also, strong wave action on the Zambian side might inhibit the development of snail populations along much of the shoreline of this inhabited area and would thus lessen the schistosomiasis problem (as has happened at certain localities at Lake Kariba).

Another potential health problem at Lake Mupata, much less certain than either malaria or schistosomiasis, would be human filariasis. Several species of filarial worms (Nematoda : Filarioidea) may cause this type of disease. The filarial parasites are transmitted from man to man by various blood-sucking insects, the larval and pupal stages of which are associated with water (the specific requirements of these vary greatly). Experience in dam-building in remote tropical areas is that the labour force is drawn from a wide area, and although routine medical examinations may be carried

out, it is quite possible to miss the symptomless carriers of filarial worms, so that carriers may be admitted to a locality where their type of filariasis is unknown but the vector is present (Edeson, 1975). The most dangerous reservoir of infection is likely to be the "camp followers" who will appear very soon after the labour force has assembled. Similarly, the resettlement of people away from the inundated area may result in the spread of filariasis if some of those who are moved are carriers.

Elephantiasis is a form of filariasis caused by Wuchereria bancrofti, which is transmitted in Zimbabwe by species of mosquitoes that also carry malaria. Elephantiasis may become a minor problem since a focus of this disease exists in the area between the Dande Valley and Kanyemba; this area is on the access route to the Mupata Gorge, and would be a source of labour, so the disease could possibly be spread to workers on the dam. However, illness normally develops only after prolonged exposure, so the disease would be a threat to permanent residents rather than to temporary workers or tourists. Another minor problem may be filariasis due to Dipetalonema perstans. The incidence of this disease appears to be related to vegetation type; it would not arise in the mopane or jesse bush that would constitute much of the vegetation around Lake Mupata but it could, just possibly, arise in localities where dense riverine vegetation occurred. Onchocerciasis, a filarial disease of particular concern on some water resource projects in Africa (such as Kainjii or Volta) would not be likely to occur around Lake Mupata due to lack of suitable breeding sites for the vector flies.

Visceral leishmaniasis, a disfiguring and often fatal disease due to protozoan parasites, has been reported recently from the Southern and Eastern Provinces of Zambia. The vectors of this disease are sandflies, of the genus Phlebotomus; it is not known if vector species occur in Zimbabwe, although close relatives of the confirmed vectors have been found. Whether the creation of Lake Mupata as such would make any difference to the chances of this disease arising in the Valley is uncertain, but it is possible that all that is

needed is for some infected people to enter the country (such as Zambian labourers) for an outbreak to occur.

Arthropod-borne viruses (arboviruses) constitute another possible disease risk that might be increased if more people are introduced to the Valley: little is known about such diseases, which occur sporadically e.g. Rift Valley Fever.

Impacts Associated with Construction and Operation of the Mupata Scheme

During the construction of the dam in the Mupata Gorge, health hazards would have to be countered by setting up a health service with adequate hospital facilities. Such a service was established with great success at Kariba Dam, at a cost that amounted to less than 0,3 per cent of the total cost of the scheme (Webster, 1960). Apart from malaria, major health problems that had to be catered for were fly-borne intestinal diseases and, of course, the high rate of physical trauma associated with any major civil engineering project. Rockfalls, dust, heat and humidity would be everyday features of a dam-building operation at Mupata Gorge. Forced ventilation and wet drilling would be required in underground workings to reduce the dust and heat.

Nearly 13 000 men worked on the dam at Kariba over a period of six years; a hundred men died, mostly from accidents (particularly road accidents on the steep, slippery and originally rough roads of the construction site) (Webster, 1960).

A health centre at Mupata Gorge would benefit the nearby tribal population of the Dande area, as would a supply of fish-protein from the lake. A point to be remembered is that local people and construction workers may be afforded temporary relief from many disease hazards (especially malaria) through an on-site health service, but they would need continued protection once they dispersed thereafter since treatment might destroy the immunities that they had gained previously through repeated, low-level infections. If an individual is thought to have some degree of immunity to malaria, it may be advisable to reduce the amount of

prophylactic drug that the person is given (i.e. suppressive therapy rather than prophylaxis) in order not to totally remove his natural protection. Obviously, the dam site would have to be maintained in a very sanitary state in order to prevent the spread of disease downstream to the Dande/Feira area. Construction camps should be sited on high ground to catch the breeze and to reduce the mosquito problem, despite the difficulties that the rocky hilltops would pose for roadmaking, sanitation services, etc.

2.13.3 Tsetse Fly and Trypanosomiasis (Sleeping Sickness) in the Valley

The protozoan trypanosomes that are transmitted by tsetse flies are obviously of great significance to pastoral agriculture as well as to human health. In view of the restrictions on agriculture in the Valley (i.e. the low carrying capacity and the designation of the area as National Parks Estate) trypanosomiasis is probably best considered as a human health problem. The entire Valley is infested with the two species of tsetse fly, Glossinia morsitans and G. pallipedes; the former is particularly prevalent in the mopane and jesse vegetation communities, and does not abound in the Mana Pools alluvial system. Cases of human sleeping sickness have been contracted at various places in the Valley in recent years. On the Zambian side, a large area (now part of the Lower Zambezi National Park) had to be depopulated due to the prevalence of this disease, and an important focus exists in the lower Luangwa Valley.

2.13.4 The Trypanosomiasis Problem with Lake Mupata

The creation of Lake Mupata would lead to a greater frequency of man-fly contact due to the fact that the shoreline would be the main zone of human activity (fishing, recreation etc.) and would coincide with the habitat of the major fly species, G. morsitans. There has been a relatively high incidence of sleeping sickness along the Kariba shoreline, despite control measures. The disease is fatal unless detected sufficiently early, and an important consideration is that overseas visitors that contracted the disease might not have their problem diagnosed correctly upon returning home.

With more traffic in and out of the Valley, there would be a greater risk of spreading infected flies to other parts of the country (during the early 1970's, an outbreak of cattle trypanosomiasis occurred in the Victoria Falls area and was thought to be due to the import of flies from Kariba via the regular airways flights).

Prophylaxis is not practicable, so a spraying programme would be essential. In order to be effective in the long-term, such a programme would have to be aimed at the elimination of tsetse fly in the Valley. The lake, forming a fairly effective barrier to Zambian flies, could be used as a starting line for aerial spraying and/or other methods of application of insecticides. There is currently a great deal of controversy in Zimbabwe relating to tsetse control programmes, since DDT is used.

2.14 ETHNOGRAPHY AND ARCHAEOLOGY

2.14.1 The History of Human Settlement in the Valley

In order to create the Zambezi wildlife areas, the tribes-people living in the Zambezi Valley between the Kariba and Mupata gorges had to be moved to communal lands south of the Escarpment in the late 1950's and early 1960's. However, many localities within the Valley are still of historical and religious significance to these people, and knowledge of the previous settlement pattern is necessary in order to understand aspects of the present-day ecology of the Valley.

Small numbers of Bushmen (Khosian hunter-gatherers) probably lived in the Valley at an early stage; their paintings have been found on rocks in the Karoi and Mukwichi areas (White, 1971). The Bushmen were displaced by Bantu people who swept south from East Africa; among these Bantu were the Va-Karanga who occupied the Zimbabwean Highveld (Guruuswa). Some of the Va-Karanga later became known as the Mkorekore ("a swarm of locusts") when they moved back towards the north, from the early fifteenth century onwards, in search of salt, and crushed lesser Bantu groups in the Karoi, Sipolilo

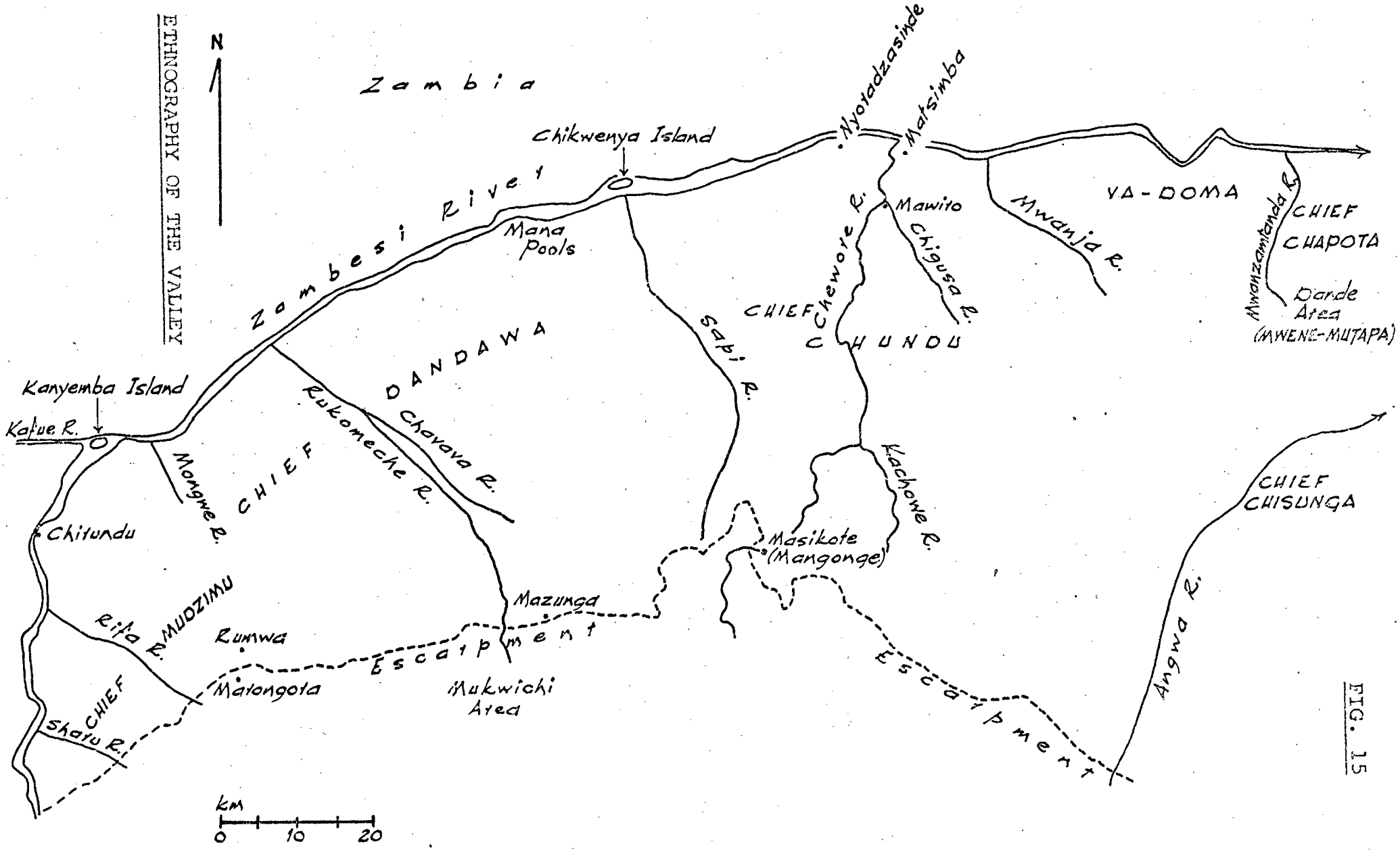

N
Zambia
Zambesi River
Chikwenya Island
Nyoladzasinde
Matsimba
Mana Pools
Mawito
Chewore R.
Chigusa R.
Mwanja R.
VA-DOMA
Mwanzamlenda R.
CHIEF CHAPOTA
Darde Area (MWENE-MUTAPA)
CHIEF CHUNDU
Sapi R.
DANDAWA
Kanyemba Island
Kafue R.
Rukomeche R.
Chavava R.
Mongwe R.
CHIEF
Chitundu
Kachowe R.
Masikote (Mangonge)
CHIEF CHISUNGA
Angwa R.
Rifa R.
MUOZIMU
Rumwa
Mazunga
Escarpment
Malongota
Mukwichi Area
CHIEF
Shatu R.
km
0
10
20

FIG. 15

and Dande areas. A large group of the Mkorekore invaders became permanently established in the Dande area, and may have been responsible for the construction, at some stage, of the rock-walled Dzimbahwe on the Utete River at the base of the Escarpment, near the present Sipolilo-Kanyemba road. A leader of these people became known as Mwene-mutapa (possibly meaning "master of ravaged lands"), and succeeding "Monomotapas" are referred to in many Portuguese records dating from as far back as the early 16th Century (Abraham, 1959). The fact that Mwene-mutapa's clan took the mutupo (totem) of Nzhou (Elephant), with the laudatory epithet Samanyanga ("owner of mighty tusks"), may be a reference to prowess as elephant hunters.

A tribe of Bantu people known as Va-Mbara were apparently widespread in the region dominated by the Mkorekore. They had to pay tribute to the Mkorekore as "the owners of the land", and their survival was apparently due to their ability to produce hoes, spears, axes and other metal goods for trade. Numerous copper ingots in the form of a St. Andrew's cross (Fig.16),weighing about 1,5-3 kg, have been found throughout the region and their manufacture has been attributed to the Va-Mbara (White, 1971). In the Valley itself, it is possible that the early Va-Mbara were eradicated by the Mkorekore since they could not have found the ores necessary for trade and survival.

A later migration of Va-Mbara from Zambia into the unoccupied western and central parts of the Valley occurred in the 17th Century (Hughes, undated). The leader of these people was Chidzere. It is probable that these Va-Mbara settled in small family groups along the Zambezi between Chirundu and the Sapi River, subsisting through riverine agriculture and hunting, and had little contact with Va-Mbara who were already living on the Escarpment. It was not long before Chidzere's people were threatened by a group of Mkorekore people from the Highveld to the south. These Mkorekore, under Mupamombe, had heard of the good availability of salt in the Valley and moved north to acquire this precious commodity. (On the Highveld, salt was scarce and of poor

quality, being commonly extracted from burnt goat droppings, whereas in the Valley good salt was extracted either from mineralized soil found at various localities or otherwise from the ashes of plants such as Salvadora and Hyphaene.)

Mupamombe's people defeated the followers of minor Va-Mbara chiefs in the Escarpment area (Chiawa was one of these chiefs, who fled north with his people). Mupamombe died and his son Nyambira continued leading the Mkorekore people north. According to legend, a group of Va-Mbara living in the Marongora area, the Venemuriga, decided to escape to the clouds and so built a tall ladder, or tower, into the sky. This structure collapsed, killing many people and leaving a large hole in the ground which later became a pool, Rumwa. A sulphur spring of this name exists just to the east of Chemutsi Dam, near Marongora, and is probably the place referred to (Hughes, undated). Nyambira tried to negotiate with Chidzere to acquire territory, but Chidzere refused to share his land and suffocated himself (Mitchell, 1961). Most of Chidzere's Va-Mbara people fled north of the Zambezi.

Chidzere's sister Changamuchiri refused to flee, saying that she would stay and die in her own country and not on foreign soil. In due course, she died and turned into a stone which is said to be found sometimes near the Chavava River and sometimes in the Mazunga area near the Escarpment. The stone is flat and has four holes (tsopero) in it, into which beer and munga cereal were placed during rain-making ceremonies. After such an offering had been made, an animal resembling a wildpig is said to have walked out of the bush and into the midst of the assembled people. It was slaughtered, and rain would fall during the ensuing feast. Changamuchiri is reputed to move of its own accord, and sometimes goes down to Mana Pools to drink and bathe. Its passage is accompanied by a roaring wind. In winter the stone sinks into the ground, and comes up again in the hot weather. R.S. Hughes, a National Parks Ranger, is evidently the only European to have seen Changamuchiri. He was shown the stone in 1970; after a long search by his informants, the curious-looking stone was found buried just beneath the

surface of the ground in an otherwise stone-free area on the Chavava River.

Nyambira and his followers soon fell into difficulties in the land that they had occupied: they suffered from famine and were harrassed by man-eating lions. Accordingly, the spirits were consulted and it was found that they were angry with Nyambira for driving out Chidzere's people. The displaced Va-Mbara were therefore invited to return and eventually the majority of them did so, to become assimilated into the Mkorekore group under what became known as the Dandawa chieftaincy. Va-Mbara rites, such as those associated with Changamuchiri, were upheld, with members of the subjugated group as spiritual officials; respect on the part of an invading group for the power of the ancestral spirits of the conquered people is common in Africa (Mitchell, 1961). Chief Dandawa's people lived in the area between the Sapi and Mongwe rivers. In 1912, 440 male taxpayers were recorded in 22 kraals under Chief Dandawa, and in 1937 the number of male taxpayers had risen to 1 095, living in 62 kraals (White, 1971). In 1958, these people were moved to Rengwe Tribal Trust Land in accordance with Government policy.

At about the same time that Chidzere and his followers had settled on the south bank of the Zambezi, a small group of Va-Sori people, led by Chimombe, had also crossed over from Zambia and had moved into the largely uninhabited area between the Sapi and Mwanja rivers. This occupation angered the Mkorekore people of the Dande area, who wished to retain control of the valuable salt pans in the land taken by the Va-Sori. The Mkorekore leader, Nyamapfeka, was determined to drive Chimombe away, but each time his warriors mounted an attack on Chimombe's people they became lost in a mysterious mist.

Frustrated in his efforts, Nyamapfeka sent his daughter Semwa (or Chiguhawa, as she was also known) to a well frequented by Chimombe's people. Here she was found and, claiming to be lost, was taken to Chimombe who was living on the Chewore River near the base of the Escarpment (at Masikote). Chimombe was struck by Semwa's beauty and

decided to marry her. When he was asleep, Semwa slit his throat. Thereafter, disasters such as total darkness, scorching heat and floods are said to have befallen the people. This period of terror went on for a long time until finally a mhondoro named Mbaiwa (grandson of Nyamapfeka) made an offering to the spirit of Chimombe. Chimombe's voice then instructed the people to dry his body. According to one of the many stories, Chimombe's body then floated on a river of blood to somewhere near the junction of the Chigusa and Chewore rivers, where it disappeared. A curious metal object later appeared in place of the body; this "Iron God" (Fig.17) is still kept and revered by the descendants of Chimombe's people, with successors of Mbaiwa as spiritual officials. Semwa was never allowed to marry again and became a mhondoro; her successors are still not permitted to marry as they are considered to be the wives of Chimombe (Hughes, undated).

The Mkorekore were impressed by the power of Chimombe's spirit and did not trouble his people further. The Matabele heard of the "Iron God" and on several occasions their impis attempted to secure it. However, Chimombe's spirit always caused great disasters to befall the raiding parties and the Matabele eventually gave up in fear. A matrilineal inheritance was practised among Chimombe's people (the successor to the chieftaincy was always the son of the last Chief's sister). The chieftaincy became known as Chundu. Other chiefs, such as Chief Chapota in the Kanyemba area, and Chief Chisunga on the Angwa River, apparently still pay tribute to Chimombe's spirit (Hughes, undated). True Mkorekore (of the mutopo Nzou Samanyanga) will not look on the "Iron God" for fear of going blind.

Up until the time that the people under Chief Chundu were moved from the Valley to the Mukwichi area (in 1963), the nucleus of the group lived mainly along the Chewore, moving up or down every few years at the request of Chimombe's spirit. Those people who lived actually on the Chewore always built their huts on the east bank of the river (Hughes, undated). Other family groups under Chief Chundu lived as far west as the Sapi, and some lived on Chikwenya Island.

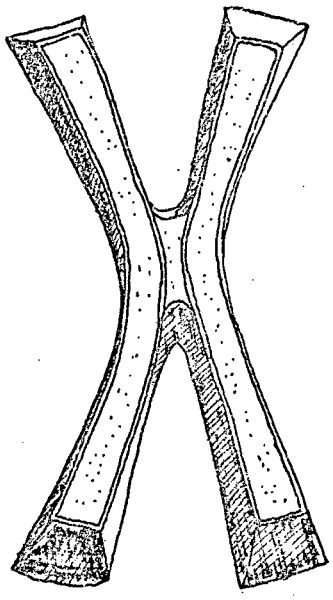
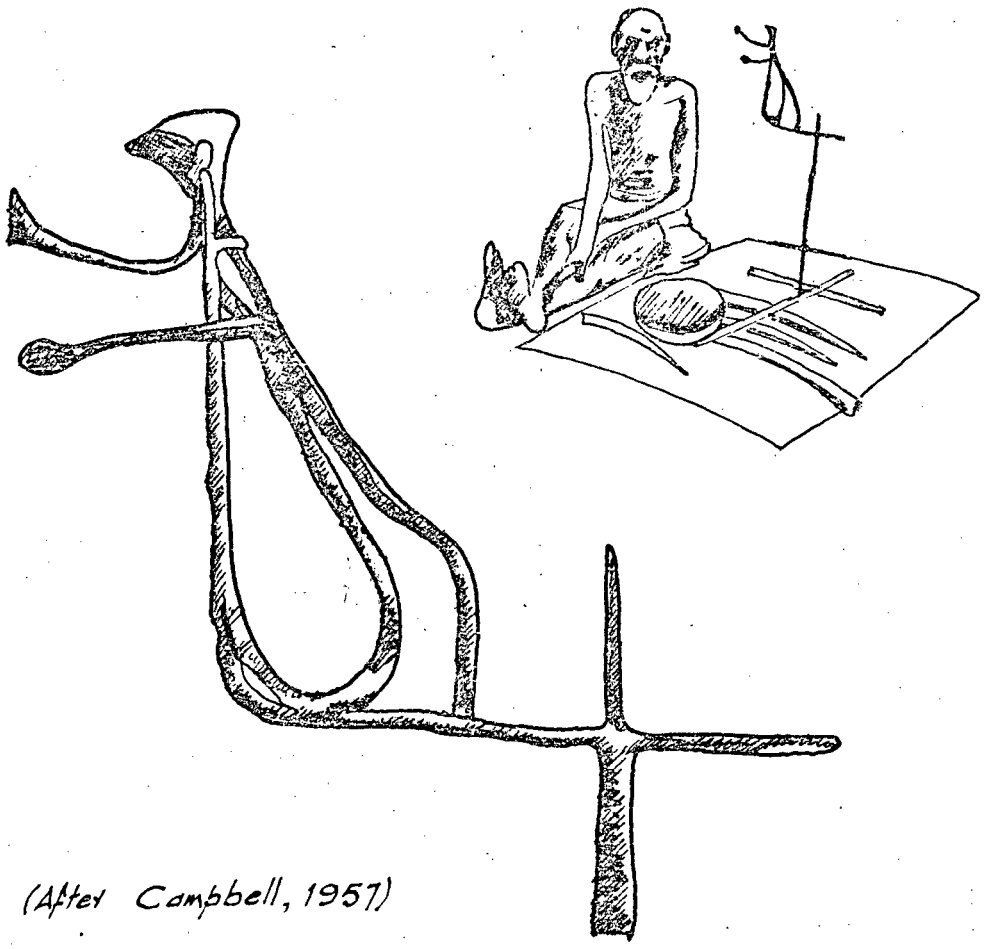


FIG. 16

A COPPER CROSS OF THE VA-MBARA



(After Campbell, 1957)

FIG. 17 CHIMOMBE THE "IRON GOD"

To the east, the people were scattered as far as the Angwa River. In 1912, 133 adult male tax payers were recorded in 8 kraals under Chief Chundu, and in 1937 the figure had risen to 227 adult male taxpayers, in 10 kraals. Apparently, Chimombe's spirit did not object greatly to the move of the people to the Mukwichi area (White, 1971). The "Iron God" was taken with the people and lives in a thatched hut made of poles from the Valley, together with his possessions of elephant tusks and a muzzle-loader rifle.

In the Chirundu area, another group of Mkorekore had occupied land originally belonging to Va-Mbara, and the Mudzimu chieftaincy was established here (White, 1971). The western boundary of this chieftaincy was the Sharu River and the eastern boundary was the Mongwe River. In 1912, the strength of the male adult taxpayers under Mudzimu was 140, in 12 kraals, and in 1937 the number was 202, still in 12 kraals. In 1953, the chieftaincy was demoted to a headman's position, under Chief Dandawa. Mudzimu's people were moved to the Urungwe area in 1956.

The Matabele, in the eras of both Mzilikazi and Lobengula, raided into the Valley on various occasions, leaving a trail of destruction behind them. Men, young children and old women were killed, while young men and older children were taken as slaves. The last raid into the Valley, some time shortly before the Pioneer Occupation, was repulsed by an alliance of the Valley chiefs, who had the advantage of guns obtained from Portuguese traders for elephant hunting (White, 1971).

Portuguese traders came up the Valley in search of gold and copper mined by the Va-Mbara. They appear to have traded with Mudzimu's people, among others. During the 19th Century the interest of the Portuguese in the Valley related to ivory rather than gold. Half-caste Portuguese with mercenary followers, known as Chikundas, are difficult to separate from true Portuguese in the legends of the Valley. One of the Chikundas was Chief Kanyamba, who established his headquarters on an island at the junction of the Kafue and Zambezi rivers. Selous (1881) records meeting Kanyemba ("a

slave-trader and a murderer") in 1877, as well as Portuguese traders on an island about 20 km upstream of Kanyamba's (at the mouth of the Lusito River?). Selous states that most of the Chikundas in the Chirundu area had flint-lock muskets, which they used for elephant hunting and for frequent raids upon neighbouring tribes. At this time, the Portuguese trade had declined considerably. Kanyemba later moved downstream to the Luangwa/Zambezi confluence.

The Va-Doma people live in a small group at the eastern end of the Valley; they came from the north at about the same time as Chimombe. In 1971, White (1971) estimated the size of the group to be about 30 families. Some members of the group show a hereditary defect of the feet, and the Va-Doma are sometimes sweepingly referred to as "the two-toed tribe". Most of the Va-Doma are primitive nomads who wander around the mountains between the Mwanja and Mwanzamtanda rivers, living on roots, honey, small game etc. The Department of National Parks and Wildlife Management does not object to their presence in the Chewore Safari Area, since they are "part of the ecology" and kill very little game. The Zimbabwean Government has recently launched a campaign to feed, educate, "politicize" and re-settle the Va-Doma (The Herald, October 9, 1981).

2.14.2 Places of Spiritual or Historical Importance in the Valley

There are numerous places in the Valley that feature in the traditions of the Va-Mbara and Mkorekore. The localities of many of the shrines or historical sites have not been clearly established. Hughes (undated) and Nduku (1982) described some of the more important religious or historical features, and those whose localities are reasonably certain are discussed below :

Mana Pools. The "main" pool (presumably Long Pool) is said to be "full of mysteries" (Nduku, 1982). Kandare, a senior member of Chidzere's group, is buried near a large strangler fig on the south side of the pool. Kandare's spirit allegedly took the form of a metal object, possibly somewhat similar to

the "Iron God" Chimombe, and was about 30 cm high. This object lived at the pool and was capable of climbing trees, but vanished in disgust after someone bathed with soap in its pool. A clear area on the eastern side of the tree is where Kandare's ceremonial hut (Dendemore) was situated, and another adjacent clear area is where the chief's indunas lived. Changamuchiri (the moving stone) washes and drinks at the pools.

Chidzere's Tree When Chidzere died, he is said to have turned into a baobab tree, which is still growing next to the Chavava River, near Nyakasikana Gate. Before Dandawa's people left the Valley, they used to gather at the tree for special ceremonies at least twice a year (Mitchell, 1961). The "tree-priest" was always a descendant of the original inhabitants of the area, who had been conquered by the Mkore-kore. Apparently the hollow tree used to contain a beehive from which honey was taken every year by a descendant of Chidzere and shared among the people (Hughes, undated). In 1925, a greedy man decided to take all the honey for himself, but upon crawling into the tree he lost most of his skin and died as a result of the wrath of the spirits. About 25 metres to the north-east of Chidzere's Tree is another, smaller baobab that is supposed to be the reincarnation of Chidzere's wife Chitunguru.

Guti This is a place, marked by a baobab, where Mudzimu's people used to hold rain ceremonies before each planting season. It is somewhere along the Rifa River (Nduku, 1982).

Mangonge The location of Chimombe's murder, on the Chewore River near Masikote. It is said to be guarded by a troop of talking baboons, and by lions, who prevent people from settling there.

Mawiro A grove of muchiriri trees (Trichelia emetica) at the old junction of the Chigusa and Chewore rivers, where Chimombe's body disappeared and the "Iron God" was found (the Chigusa eroded a new mouth in 1938). A large fig tree near Mawiro, known as Mutowe wa Kamandu, contained a beehive which was never robbed since the honey belonged to Chimombe.

This tree is the burial site of Kamandu, the fourth Chief Chundu (Hughes, undated).

Matsimba A few hundred metres from the Chewore airstrip, near some jesse bush, is a rock in which the footprints of a lion are marked. It is said that the spoor was left in the mud after the great flood at the time of Chimombe's murder (Hughes, undated).

Nyoradzasinde The "iron writings of Chimombe", as they might be called (alternatively, the "tattoos on the girls"), consist of a pattern of squares weathered into flat slabs of sandstone. The writings are near the point where the Mombe (Endamombi?) stream flows into the Zambezi, west of the Chewore mouth. A human footprint was evidently also outlined in the rock, but has been damaged by vandals (Hughes, undated; Nicolle, 1937).

2.14.3 The Loss of Places of Religious, Historical or Archaeological Significance due to the Mupata Scheme

Since the tribespeople were moved out of the Valley, they have apparently stopped conducting their ceremonies at the old sites. The need for some ceremonies has fallen away because the spirits that were appeased were only important to life in the Valley itself e.g. Chidzere's spirit (Mitchell, 1961); also, alternative sites have been found for some ceremonies (Nduku, 1982). However, the spirits apparently wish the people to return to the Valley, and now that the Rhodesian War has ceased, it should be possible for the people to perform some of their rites, when required, at the original localities. Despite this possibility, many of the people feel that their spiritual requirements cannot be met through compromises; they are apathetic or resentful due to their forced translocation. Many of the younger generation are now detached from the sentiments and customs of their forebears, and do not wish to return to the Valley.

Whether or not the sacred places in the Valley will retain their religious significance much longer is uncertain, but these places have increasing historical importance. The

events that took place in the many centuries of human occupation prior to the advent of Western civilization in this country will seem very abstract unless the localities or objects associated with them are preserved.

Since the precise locations of some of the sites of historical or religious importance are known to only a few of the resettled tribespeople, it is difficult to say just which sites would be inundated by Lake Mupata. It seems likely that Mawiro and Mutowe wa Kamandu would be lost, and it is possible that Matsimbe and Nyoradzasinde would be just under water. There are various other lesser sites around the Chewore mouth (Hughes, undated) that would be flooded. The Mana Pools sites would be certain losses, and Changamuchiri may not take kindly to having to bathe and drink in the lake-water. Obviously, the creation of Lake Mupata would give much of the remaining Valley a very different character, and the legends of the old tribespeople would not relate to the environment as well as they do at present.

Ruined Portuguese (and/or Chikundu) settlements on the islands near Chirundu would be in danger of being flooded (the altitudes of these islands, such as Kanyemba, are uncertain). As regards ancient history, N. Walker (Curator of Archaeology, Salisbury Museum, pers. comm.) feels that the riverine area along the middle-Zambezi is not as rewarding for archaeologists as other parts of the country, but thinks that the environment here may have given rise to unique subsistence strategies during the Stone Age. During a brief survey in 1981, Walker found a few archaeological sites (such as an Early Stone Age factory site in a low sandstone outcrop near Vundu Camp) and concluded that further archaeological work should be carried out prior to the inundation of the area.

2.15 RECREATION AND TOURISM

2.15.1 The Attraction of Mana Pools

After a long period of closure during the war, the Mana Pools National Park is now a major attraction for wildlife enthusiasts in Zimbabwe. A limited number of visitors (maximum of

50 cars at one time) are permitted to stay in the park during the period 1st May to 31st October; outside this period the roads near the river become too muddy to allow tourist traffic. It is the alluvial system on the Zambezi, an area of only about 80 km^2 in extent, that is the focus of tourist attention since the Acacia woodlands, high animal densities and grandeur of the Zambezi River constitute a unique wilderness that rivals the better known East African wildlife areas. A central camp on the edge of the Zambezi, Nyamepi, is 4 ha in extent and consists of 45 caravan/camping sites, with some ablution blocks. During 1981, two "remote" camp sites (limited to one vehicle/party) were available at Nkupe, about 1 km to the east of Nyamepi, and at Mucheni, 8 km to the west; these had no facilities apart from "long-drop" toilets and fireplaces. The Department of National Parks and Wildlife Management is presently producing a development plan for the Valley, and additional tourist facilities will be made available during 1982 in accordance with this plan (care is to be taken to minimize tourist impact on the alluvial system). There is a possibility that an educational camp may be established for schoolchildren on the Rukomechi River. The safari areas (Urungwe, Sapi, Chewore) may be elevated to National Park status in the future if this is justified by public demand for further non-hunting wilderness recreation.

Traditionally, Mana Pools has been a fisherman's haven, but there now appears to be some conflict between the advocates of unspoilt wilderness and the fishermen, who use power boats on the river and whose extraction of fish is in itself a contravention of the purer ideals of wildlife preservation. This problem was one of the themes to emerge from a survey of tourists that was conducted at Mana Pools during 1981. Another theme was the appreciation that people felt at being permitted to stroll around the parkland, without guides; this is permitted at Mana Pools, in contrast to other parks containing big game, due to the good visibility that is afforded to both the tourists and the animals, reducing the possibility of sudden, dangerous encounters. During the survey, 123 questionnaire forms were completed by visiting parties, of which 90 per cent expressed a desire for the creation of

walking trails, as opposed to additional roads for vehicle travel. There is a clear need for interpretive facilities. When asked if the park was overcrowded with tourists, 72 per cent of respondents answered "no"; it seems that the present policy of providing one large central camp so that human pressure is concentrated at a particular locality, keeping the rest of the alluvial area as untouched as possible, is sound while the emphasis remains on game-viewing from vehicles. Perhaps in the future, when the demand for the "African wilderness experience" rises, it would be desirable to have the main camp away from the river frontage and to develop a system of walking trails and overnight camping spots (each with the basic facilities of a "long-drop" and a fireplace) rather than a road network that could carry a lesser amount of people before reducing the wilderness quality of the sensitive alluvial area.

The Department of National Parks and Wildlife Management keeps entry fees and camping fees as low as possible, and access to the park is democratically controlled by a "waiting-list"system. However, it has been realised that the area has the potential to generate substantial revenue from wealthy (mostly foreign) tourists who are prepared to pay high fees for exclusive tours. Permanent structures could not be built within the park by tourist organizations wishing to exploit this potential, but small areas have been demarcated on either side of the park where non-hunting safari operations could be based. At least one of these sites, near the Sapi confluence, is to be utilized during 1982 for a "low density/high cost" tourist operation (12 bed tented camp). The general opinion of leading operators in the non-hunting safari business is that the Mana Pools alluvial system could be best utilized as a 4-5 day stop-over for small groups on package tours, providing an additional facet to complement tourist attractions such as Victoria Falls, Wankie and Lake Kariba.

2.15.2 The Attraction of Lake Mupata

In the tourist survey mentioned previously, 100 per cent of the respondents said that they wished to return to Mana Pools (with an average desired stay of 7,8 days per year), whereas

only 43 per cent said that they would be interested in holidays at Lake Mupata (3,4 days per year). It may be true that many people who went to the trouble of completing and returning the questionnaires were wildlife enthusiasts who regarded the Mupata scheme as anathema, but on the other hand it may be presumed that fishermen who were likely to benefit from the creation of the lake would have made a similar effort to express their point of view. The results of the survey can by no means be regarded as the "average Zimbabwean tourist's response" to the choice between Mana Pools and Lake Mupata; however, taken in context the results are still significant in proving that the creation of the lake would entail the loss of a major recreational amenity. Professional operators of non-hunting safaris emphasized the need for diversity in the tourist attractions that a country is able to boast, and felt that Lake Mupata would be too much like Lake Kariba, whereas Mana Pools is unique.

In fact, Lake Mupata would probably be somewhat less attractive for tourists than Lake Kariba, once its initial novelty wore off, due to the navigational difficulties (weed mats, shallowness, submerged trees, bands of rushes and reeds), the unattractive shoreline on the Zimbabwean side (monotonous mopane woodland and dense jesse thickets) and lack of services. A feature of the Mana Pools alluvial system is the apparent absence of tsetse flies that abound in the mopane and jesse areas; tourists on the shoreline of the new lake would be plagued by these pests. When asked if they thought that the area between the alluvial system and the Escarpment was worth developing for tourists at present, 67 per cent of respondents in the questionnaire survey said "no", indicating that the portion of the Valley remaining after the creation of Lake Mupata would not constitute much of a tourist attraction even for wildlife enthusiasts. Fishermen would find the new lake to contain abundant good-sized fishes such as bream species, Tigerfish and Vundu, but the creation of this new lacustrine fishing attraction would involve the loss of Zimbabwe's major big-river fishing attraction.

2.16 SAFARI HUNTING

(Information derived from the contributions of Booth, 1981, and Stanning, 1981)

2.16.1 Safari Hunting in Zimbabwe

The safari industry in Zimbabwe has developed steadily since the early 1960's, despite the setbacks suffered during the war years. Today this industry generates a substantial amount of foreign currency and provides employment for a large number of people. The viability of the industry, with its high overheads, is obviously dependent on the number of trophy animals available, especially of key species such as Elephant, Buffalo, Lion and Leopard. Only a limited number of hunters are able to afford such safaris and thus the business is extremely competitive. The successful safari operators have taken a number of years to establish themselves and to build up their reputations in the hunting fraternities of Europe and America.

The income of a safari operator is obtained largely through the number of hunter-days that are generated during the hunting season. Hunter-days are the number of days that a specific hunt is booked for and not the actual number of days spent hunting. For example, if a company offers a 10-day Buffalo safari and the trophy is bagged after 5 days, the client is liable to pay for a full 10-day safari even though he may have stopped hunting immediately after shooting his Buffalo. The number of hunter-days that comprise each safari vary according to the desired trophies. For example, Elephant bulls may be shot on a 21-day safari, Buffalo on 10-day safaris and antelope on safaris of 7 days or less (these figures have been generalized; safari operators offer various "deals" in order to generate as many hunter-days as possible). The average daily rate charged to the client in 1981 (exclusive of Government trophy fees) was US$550 per day (hunters usually bring a companion, making the average daily rate US$625 per day). Hence, if the Elephant quota (for instance) is reduced for an operator by one animal, it means that the operator stands to lose the income from a 21-day safari worth US$12 000 or more.

The setting of quotas by the Department of National Parks and

Wildlife Management is based on the estimated status of each animal population, which varies according to factors such as habitat reduction and disease. Since the economics of the safari industry are so finely tuned to the numbers of key species available, reductions in quotas need careful consideration before they are implemented.

2.16.2 Safari Hunting in the Valley

The Urungwe, Sapi and Chewore safari areas have been reserved largely for local usage in the past. Camps were sited at intervals along the Zambezi River and on or just below the Escarpment. People submitted their applications to hunt in specified areas and were selected by the authorities through a lottery process. General game licences could be purchased by the lucky applicants to cover antelope and lesser species, while specific licences were required for the hunting of Elephant, Buffalo, Lion and Leopard. During the war, hunting in the Valley was virtually curtailed. Once hostilities ceased, it was decided to change the previous pattern of hunting in order to generate greater revenue from the area. Accordingly, those wanting a specified hunting concession in the Valley were invited to place a tender and the highest bid was taken. The new system resulted in the intended increase in revenue, with all 133 concessions in the Zambezi Wildlife Estate being eagerly sought; bids for some 14-day hunts ran to around Z$10 000. Many of those who submitted tenders in 1981 were commercial safari operators who used their concessions for hunting by foreign clients. The hunting season in the Valley is from 1st May to 31st October.

A questionnaire survey of safari operators was carried out to establish how they rated various hunting areas in Zimbabwe, according to certain factors. The results, shown in Table 12, indicate that the safari areas of the Valley are very attractive for commercial hunting.

2.16.3 Effects of the Mupata Scheme on Safari Hunting

Hunters on safari tend to be somewhat single-minded in their desire to secure prize trophies, and the character of the country in which they hunt is generally of subsidiary

TABLE 12

RANKING OF SOME ZIMBABWEAN SAFARI AREAS ACCORDING TO VARIOUS FACTORS

FACTOR	1 (best)	2	3	4	5	6 (worst)
Trophy size	Matetsi	Sapi Urungwe Chete Chirisa	Chewore	Lowveld	Midlands	
Species diversity	Matetsi	Sapi Urungwe Chete Chirisa Chewore	Lowveld	Midlands		
Rarity of species	Matetsi Sapi Chewore Urungwe Chete Chirisa	Lowveld Midlands				
Atmosphere (African experience)	Sapi Urungwe	Chewore	Chete Chirisa	Matetsi	Lowveld	
Accessibility	Matetsi	Midlands	Lowveld Urungwe	Chewore Sapi	Chete	Chirisa

importance to the availability of game. Thus, although concessions in the Valley that enable camping on the edge of the Zambezi River are particularly popular. the main impact of Lake Mupata on hunting would come through its adverse effect on large mammal populations, with the inundation of the scenic riverine area being of lesser significance. As discussed in 2.8.2, the former effect would come about due to the decrease in the overall mammal carrying capacity of the Valley with the loss of the Zambezi alluvial system; since any reductions in quotas are keenly felt by the safari industry, this would have serious economic repercussions, as shown by Stanning (in preparation). The proposition that, in the short-term, increased quotas might be made available to hunters due to the need to cull certain species is not feasible because culling operations require great efficiency and considerable scientific involvement to be successful; hence well-trained culling teams are essential. On the positive side, the Mupata scheme would facilitate communications, and some safari clients might find the fishing attractive, although they can presently fish in the Zambezi River anyway.

2.17 MAN-MADE STRUCTURES AND COMMUNICATIONS

2.17.1 Man-Made Structures and Communications in the Valley

The Valley is one of the most undeveloped parts of the country. The only village is the small border post of Chirundu; apart from this, people are permanently resident at the Rukomechi Tsetse Research Station and at the Mana Pools and Chewore camps of the Department of National Parks and Wildlife Management. The only tarred road is the Makuti-Lusaka road, crossing the Zambezi River via the Chirundu Bridge (completed in 1939). All-weather gravel roads are the "security road" running along the base of the Escarpment from the Makuti-Chirundu road to the Angwa Bridge in the Dande area, and the road to Mana Pools. Since the cessation of hostilities, safari operators have opened up tracks in the hunting areas, although not all roads in the Chewore area have been checked for landmines.

2.17.2 Impacts of the Mupata Scheme on Man-Made Structures and Communications

Very few buildings would be inundated; these would essentially be the staff quarters and tourist facilities at Nyamepi Camp (Mana Pools), the quarters of the Ranger in charge of the Chewore area, possibly some buildings at Chirundu (buildings on the Chirundu Sugar Estate appear to be ruined anyway) and a few camps that are temporarily occupied by hunters and fishermen. A loss would be the fort at Mana Pools in which National Parks personnel lived during the recent war; this well-made structure might be of historical interest in years to come. The road approaches to the Chirundu Bridge and the approach spans of the bridge itself would require alterations that are estimated to amount to about a quarter of a million dollars (at current costs). Two sections of the Chirundu-Makuti road would have to be raised; it is thought that the changes to the road may be within the scope of road retirement works that are planned anyway.

The tarred access road that would be required for the construction of the Mupata Dam would obviously enhance communications in the Kanyemba area, although it should be pointed out that there is little scope for development here apart from the hydro-electric scheme, and the existing all-weather gravel road from Sipolilo meets the present requirements of the local people. However, the dam would provide another road-link with Zambia, and, if the economy of Central Africa improves, a rail-link between Salisbury and Lusaka could be aligned across the dam.

Much publicity has been given to the possibility of a "waterway to the sea" for Zimbabwe; it has been suggested that barges could ply up and down the Zambezi River, carrying the country's imports and exports at relatively low costs. A system of dams, locks, dredged channels and ship-lifts would be required. Mitchell (1981) states: ".... the key to the possible commercial navigation of the Zambezi is the Mupata Gorge Dam ...." However, the section of river below Cabora Bassa has so many sand bars that considerable engineering work would be required here before barge-navigation in the middle-Zambezi section could be considered, and it

does not seem likely that Mocambique would readily help finance the construction of at least three locks on the lower Zambezi, since it would not need the transport route. Also, some basic economic questions have yet to be answered: what would be sent down the waterway, and why should the waterway be a cheaper means of transport for Zimbabwe than a more direct rail-link? Overall, the "highway to the sea" seems a fanciful notion at this stage in Zimbabwe's development, and the usefulness of Lake Mupata in terms of water transport would be in a local rather than a regional context.

3 THE BATOKA SCHEME

3.1 CLIMATE

3.1.1 Current Climatic Conditions in the Victoria Falls Area

No meteorological data are available for Batoka Gorge itself; the two nearest stations at which observations have been made are the Victoria Falls Police Camp, in the town of Victoria Falls, and the Victoria Falls Airport, about 18 km south of the town and about 16 km south-west of the Zambezi.

It can be seen from Tables 13 and 14 that rainfall (600-700 mm per annum) occurs in a single season around December, January and February; the hottest month is October, when daily maximum temperatures are around 34° C, and the coolest month is June, when the daily maximum temperatures are around 25° C.
The prevailing winds are from the east, blowing at a daily mean of just over 4 knots during most of the year; this average speed increases to around 6 knots in September and October. The winds back (develop a more northerly component) during the day, to reach peak speeds between 1000 hours and 1200 hours (averaging about 10 knots at this time during September-October). In the afternoon the winds veer (develop a more southerly component) and weaken. In January the winds remain somewhat more northerly than in the rest of the year. Gusty conditions are relatively infrequent, but gusts reaching or exceeding 45 knots occasionally occur at Victoria Falls during November and December, associated with thunderstorms.

3.1.2 Climatic Effects of Lake Batoka

(Information derived from the contribution of Torrance, 1981)

> "No measurable climatic effects on the surrounding country are expected, other than microclimatic changes on the gorge walls where the riverine vegetation should redevelop at a higher level."

The Batoka Gorge is a deep, winding gash in the countryside, rather than a funnel extending from lowland into higher terrain (such as Kariba Gorge), so winds in the Gorge, with or without Lake Batoka, are unlikely to be stronger than over the surrounding area.

TABLE 13

CLIMATOLOGICAL DATA FROM VICTORIA FALLS POLICE STATION

LOCATION 17° 56' S 25° 50' E ALTITUDE 925m

PERIOD December, 1933 - January, 1948

	Mean Daily Maximum Temp.(°C)	Mean Highest Maximum Temp.(°C)	Absolute Maximum Temp.(°C)	Mean Daily Minimum Temp.(°C)	Mean Lowest Minimum Temp.(°C)	Absolute Minimum Temp(°C)	Rainfall (mm)
JUL	26,8	30,9	32,2	5,6	1,1	-3,6	0
AUG	29,2	33,2	36,7	8,3	2,8	-1,7	∅
SEP	33,5	38,0	40,0	13,4	7,4	5,0	1
OCT	35,7	39,7	42,2	17,6	12,0	8,3	25
NOV	34.4	39,3	41,1	19,2	14,9	10,6	72
DEC	31,7	37,0	39,4	19,1	15,1	8,9	179
JAN	30,9	35,7	37,8	19,3	16,6	13,9	186
FEB	31,0	34,8	37,8	19,1	16,2	13,3	138
MAR	31,4	34,7	36,7	17,8	13,7	11,7	91
APR	31.5	34,5	36,7	15,3	10,7	5,6	21
MAY	29,3	33,3	35,6	9,9	5,3	1,7	2
JUN	26,1	30,5	32,8	6,6	1,1	-2,8	1
YEAR	31,0	35,1	42,2	14,3	9.7	-2,8	716

The symbol ∅ has been used to indicate a value which is greater than 0 but not as much as 0,5.

TABLE 14

CLIMATOLOGICAL DATA FROM VICTORA FALLS AIRPORT

LOCATION 18° 06' S 25° 51' E ALTITUDE 1062 m PERIOD July,1967 - June,1976

	Mean Daily Maximum Temp.(°C)	Mean Highest Maximum Temp.(°C)	Absolute Maximum Temp.(°C)	Mean Daily Minimum Temp.(°C)	Mean Lowest Minimum Temp.(°C)	Absolute Minimum Temp.(°C)	24 - hour Mean Temp.(°C)	24 - hour Rel. Humidity (%)	24 - hour Mean Pressure (m/bar)	Daily Sunshine (hours)	Evaporation (mm)	Rainfall (mm)	Mean Wind Direction(degrees)	Mean Wind Speed (knots)
JUL	24,8	28,7	30,7	6,0	1,7	-0,1	15,1	47	900,4	10,0	136	0	096	4,3
AUG	27,5	31,9	34,3	8,8	3,9	-2,1	18,1	39	898,6	10,2	181	0,6	096	5,6
SEP	31,2	35,5	36,8	13,0	7,5	4,2	22,2	33	896,3	10,3	232	3,5	098	5,9
OCT	33,2	37,4	38,7	17,5	12,7	9,9	25,3	38	894,5	9,2	261	24,7	095	6,5
NOV	31,3	36,5	38,1	18,0	13,9	11,4	24,1	56	894,3	7,7	206	74,0	082	5,5
DEC	29,4	33,9	38,2	18,1	15,0	11,5	22,9	70	893,9	6,3	166	168,1	076	4,6
JAN	28,7	32,3	35,8	18,3	15,0	12,9	22,6	76	892,8	6,6	154	160,1	065	4,1
FEB	28,6	31,8	33,7	17,8	14,8	11,2	22,4	75	893,0	7,8	145	123,5	082	4,4
MAR	29,0	31,8	35,3	17,0	12,9	10,7	22,2	71	894,8	8,0	161	66,9	092	4,7
APR	28,4	31,9	34,2	14,1	9,7	7,7	20,7	65	896,5	8,7	144	22,4	093	4,3
MAY	26,9	31,1	32,1	9,7	4,4	1,0	17,8	55	898,2	9,5	140	5,5	098	4,2
JUNE	24,2	28,2	29,7	5,8	1,7	-4,3	14,6	51	900,3	9,5	121	0,2	097	4,0
YEAR	28,6	32,6	38,7	13,7	9,4	-4,3	20,7	56	896,1	8,7	171	649,5		

3.2 GEOLOGY AND GEOMORPHOLOGY

3.2.1 General Geology of the Batoka Gorge Area

(Information derived from Merz and McLellan, 1981)

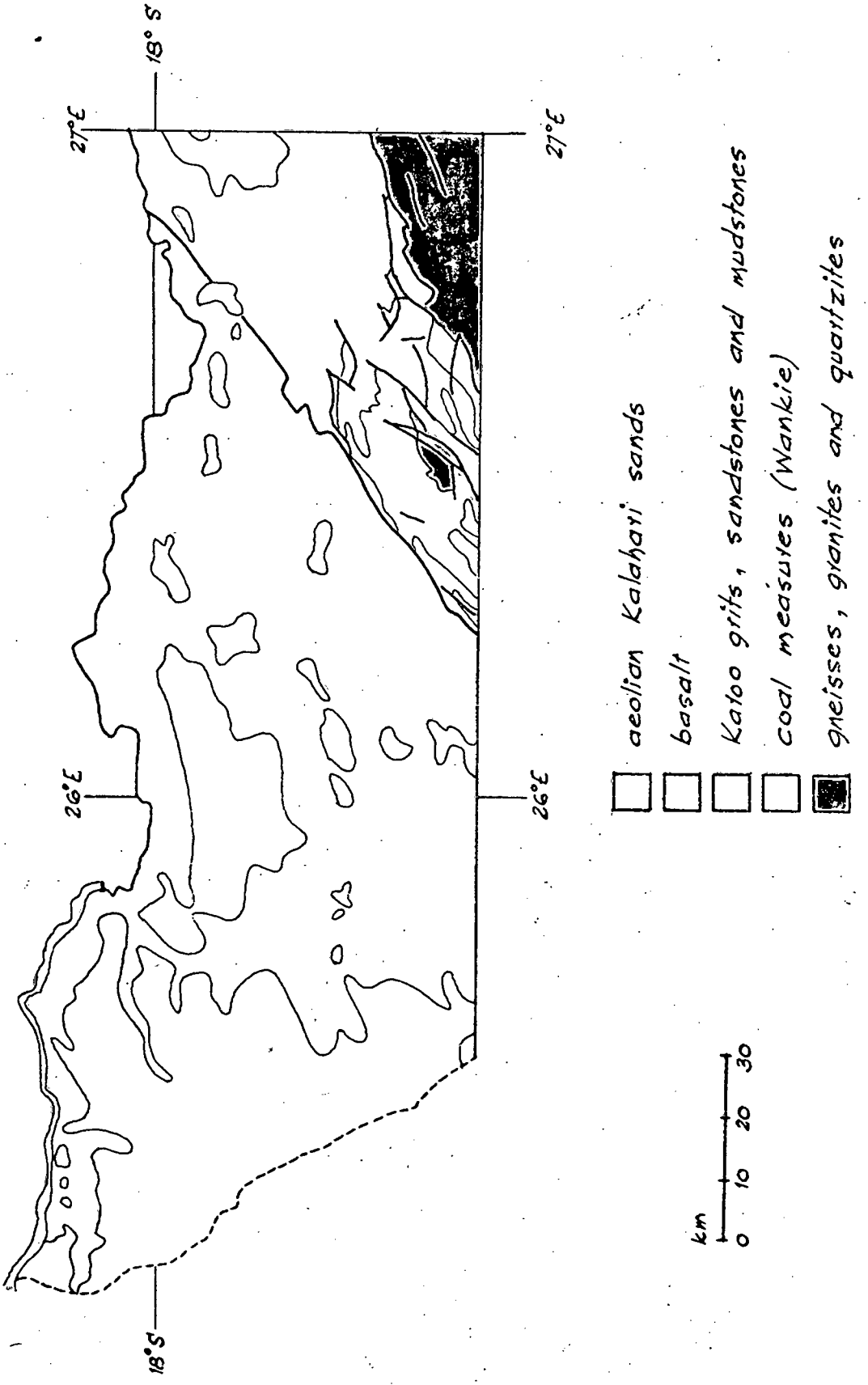
The Batoka Gorge area is underlain by a thick sequence of near-horizontal basalt lava flows belonging to the Karoo system of Jurassic age (about 150 million years B.P.). Several individual flows can be recognised in the cliffs of the Gorge, with each flow having a massive, jointed central part and a rubbly top and bottom. Locally the lavas are overlain by windblown sands of the Pleistocene Kalahari system. A major feature of the area around the Gorge is the well-developed system of faults (joints?) in the Karoo basalt. Some mineralization and alteration has occurred along these faults with the consequent formation of secondary minerals, including chlorite, and extensive veining. These rocks along the faults are somewhat softer than the unaltered basalts and have been eroded to form steep-sided vallies and gullies. The faulting apparently occurred prior to the deposition of the Kalahari sands; some joints may have formed as shrinkage cracks when the lavas cooled, but the east-west sets have been emphasized by later crustal movements (Bond, 1975).

3.2.2 Erosion and Deposition in Batoka Gorge

It seems likely that in the geological past the upper-Zambezi flowed south through the Makarikari area of Botswana and joined the Limpopo River, and the middle Zambezi was a completely separate river system (Bond, 1975). A gentle upwarp south of the Makarikari area may have broken the Zambezi-Limpopo connection and impounded the water in the Chobe-Makarikari swamp system; the water would have overflowed into the middle-Zambezi headwaters, forming a waterfall on the west flank of the present Matetsi Valley. The modern course of the Zambezi was thus established in the earliest Pliocene (Lister, 1980). At the end of the Pliocene and passing into the Pleistocene, severe crustal warping resulted in the new base levels being formed, and the Quaternary erosion cycle was initiated (Lister, 1980). A nickpoint between this erosion cycle and the slightly older post-African is represented by the present line of the Victoria Falls, which is only a (geologically-speaking)

FIG. 18

GEOLOGY OF THE AREA AROUND THE GORGE



(After National Geological Survey Map, 1977)

temporary feature in the process of upstream retreat of the waterfall from the Matetsi confluence. The zig-zag form of the Gorge and the steepness of its walls are due to the presence of the joints in the basalt, along which the river channel has been eroded. In time, the nickpoint will move upstream out of the area of jointed basalt that is suitable for the development of a waterfall and will become less well-defined.

Virtually no deposition takes place within the Gorge because the speed of the current is so great and because the upper-Zambezi water has a very low sediment content (material is left in the upstream swamp sections).

3.2.3 Effects of the Batoka Scheme in Relation to Erosion and Deposition

Due to the hardness of the basalt walls of Lake Batoka, shoreline erosion would be insignificant, and with the low sediment input (see 3.10.1) the rate of siltation would be extremely slow.

3.2.4 Mineral Potential of the Area around Batoka Gorge

(Information derived from the contribution of Anderson, 1981)

The Karoo lavas and Kalahari sediments are barren of minerals.

> "The nearest known deposits (coal, cassiterite, wolframite, fluorite, copper, fireclay, lead, tantalite and mica) are spread from the vicinity of Wankie to east of Kamativi. Potential exists at Katete, north-west of Kamativi, for phosphate and limestone, and in the Karoo sediments extending from Robins Camp eastward for uranium discoveries."

3.2.5 Effects of the Batoka Scheme in Relation to Exploitation of Mineral Deposits

(Information derived from the contribution of Anderson, 1981)

> "Access roads and water supplies associated with the Batoka scheme would be remote from mineral deposits and would therefore have no influence on their exploitation."

The Wankie thermal station should meet the requirements of the

mining industry in the region for many years to come.

3.2.6 Seismicity in the Batoka Gorge Area

(Information derived from Merz and McLellan, 1981)

The Gorge is in an area of low to moderate seismic activity with numerous events of magnitude less than $M_S = 3,5$ occurring each year. No particularly strong earthquakes have been detected in the vicinity of the dam site. The distribution of shocks in the Batoka Gorge area suggests that they may be associated with the faulted contact between the Karoo basalts and the Karoo sediments, which outcrop to the south-east of the Gorge, around Wankie.

3.2.7 Seismic Effects of Lake Batoka

Being so small, the reservoir would be unlikely to induce significant seismic activity. Any shocks that might occur would be most unlikely to damage the wall.

3.3 SOILS AND IRRIGATION POTENTIAL

3.3.1 Soils and Irrigation Potential of the Batoka Gorge Area

The terrain in the vicinity of the Gorge is very broken, with much basalt rubble, and 5-10 km to the south an extensive area is overlain by sandy Kalahari soils. The greatest irrigation potential is that of isolated patches of deeper basalt soils where the slopes are moderate, and of pockets of alluvium in the major river valleys, such as the Deka and Matetsi. No soil survey has been carried out in the area, and no irrigation has been attempted.

3.3.2 Irrigation Potential with Lake Batoka

Although it would probably not be worthwhile to pump water to any soils along the Gorge, the irrigation potential of the Kalahari soils to the south, though slight, should not be disregarded. With increasing research into useful plants of semi-arid zones, such as the oil-yielding Jojuba (*Simmondsia* sp.), it is likely that the easily-tilled Kalahari soils of this inhabited area will be used for the commercial production of some crop before long, and the availability of water from Lake Batoka might become significant.

3.4 VEGETATION

3.4.1 Vegetation of the Batoka Gorge

(Information derived from the contribution of Muller and Pope, 1982)

"The vegetation within the Gorge for a distance of 40 km upstream of the Moemba Rapids was briefly sampled by listing the woody species and recording their cover abundance according to the Braun Blanquet scale. Eleven sites were sampled, in October, 1981, selected subjectively to include all apparent environmental variation and species composition."

"The investigation revealed three main vegetation types, and these appeared to be related to the slope and proximity of the river.

These are as follows:

i) Riparian vegetation This consists of a narrow fringe of riverine trees along the Zambezi River flood-line. This fringe only becomes broader at occasional bends in the river channel where there is more flat ground. The main tree species include Diospyros mespiliformis, Garcinia livingstonei, Mimusops zeyheri, Manilkara mochisia, Ficus ingens, Trichelia emetica and Rhus quartiniana.

Where the fringe is better developed Acacia nigrescens, Lonchocarpus capassa, Triplochiton zambesiacus and Combretum imberbe can occur.

Common shrubs are Friesodielsia obovata, Securinega virosa, Bridelia cathartica, Nuxia oppositifolia, Jasminum stenolobum, Tiliacora funifera, Artabotrys brachypetalus and Hippocratea africana. The last three can grow into lianas.

ii) Colophospermum mopane woodland This is a mopane-dominated open woodland with scattered shrubs and a grass cover. It occurs only on the flatter slopes of the Gorge, found downstream towards Moemba Rapids. Slopes of approximately 20° and bare rock outcrops of up to 50 per cent of the area are typical

in this vegetation type. The dominant trees are Colophospermum mopane and Combretum elaeagnoides. Other common trees are Commiphora mollis, Terminalia stuhlmannii, Erythroxylum zambesiacum, Combretum apiculatum, Sclerocarya caffra, Diospyros quiloensis, Lannea discolor, Kirkia acuminata, Terminalia prunioides, Sterculia africana, Commiphora pyracanthoides and Commiphora mossambicensis.

The common shrubs are Gardenia resiniflua and Carphalea pubescens.

Occasionally Commiphora mollis dominated thickets were observed below the mopane woodlands where the gorge slopes become flatter.

The associated tree species found in these thickets are Commiphora caerulea, Diospyros quiloensis, Acacia senegal var. leiorhachis, Terminalia stuhlmannii and Kirkia acuminata. The shrub species in these thickets are Grewia flavescens, Gardenia resiniflua, Vitex petersiana, Grewia bicolor and Pavetta gardenifolia.

iii) Mixed species woodland This is a dense woodland with a thick shrub cover, becoming more open up the slopes of the Gorge. It occurs on the steep 25-30° slopes between the river bank and the foot of the cliffs and is found in the middle and upper regions of the section of gorge upstream from Moemba Rapids. Rock outcrops comprise about 60 per cent of the area. A more detailed study would perhaps define two to three sub-types of this woodland, related to the proportions of boulder scree and rock outcrop. Important tree species are Commiphora caerulea, Markhamia acuminata, Gyrocarpus americanus, Diospyros quiloensis, Entandrophragma caudatum, Sterculia africana, Kirkia acuminata, Albizia brevifolia, Terminalia prunioides, Commiphora mollis and Commiphora marlothii.

Triplochiton zambesiacus is common to dominant in places, while Ficus glumosa and Ficus soldanella are conspicuous but occasional. Afzelia quanzensis is common on the lower slopes.

The shrub layer contains Croton menyhartii, Gardenia

resiniflua, Hippocratea buchananii, Grewia flavescens, Strophanthus kombe, Tricalysia junodii, Euphorbia espinosa and occasionally Euphorbia cooperi. Shrub forms of some tree species are also an important component of this woodland. Fockea multiflora is common in the shrub layer and often as a liana climbing into trees."

3.4.2 The Impact of Flooding on the Vegetation

"Since the woody species recorded in the area that would be submerged are common elsewhere there is no threat of a species becoming extinct. Of the three vegetation types described, the riverine vegetation and the Colophospermum mopane woodland are both well represented in the area of Batoka Gorge which would not be flooded, and are common elsewhere. The mixed species woodlands are not known to occur outside the Gorge and the areas where they are best developed would be submerged. However, sufficient of this vegetation type occurs above the floodline to prevent it from being totally lost. Any riverine fringe development along the new shoreline would depend on the presence of a scree slope."

3.5 TERRESTRIAL INVERTEBRATES

3.5.1 Terrestrial Invertebrates of the Batoka Gorge Area

(Information derived from the contribution of Phelps, 1981)

"There is no detailed knowledge of all the terrestrial invertebrate groups in the Batoka Gorge and its environs. The Gorge may contain some specialized habitats, but the walls of the gorges along the Zambezi and its tributaries are inhospitable places, and do not carry large populations of invertebrates. The area between the Gorge and the Bulawayo-Victoria Falls road has been sparsely settled for a long period of time, and the habitats have suffered some of the consequences of human settlement. Most of this area is barren, with poor soils, low effective rainfall and high temperatures."

3.5.2 Impacts of the Batoka Scheme on Terrestrial Invertebrates

The Impact of Inundation and Water Control

"Filling the lower levels of the Batoka Gorge will remove some invertebrate habitats but fairly similar habitats will remain in the downstream gorges (Devils Gorge and Kariba Gorge), and on some of the Zambezi's tributaries. Elimination of any terrestrial invertebrate species is therefore unlikely. The species diversity in the area of Batoka Gorge is unlikely to change, and flooding will not have much impact on the numbers of terrestrial invertebrates. As the lake will be confined within the Gorge, variations in water-level will not create any new habitat types, and it is unlikely that any invading species of terrestrial invertebrates will become established."

The Impact of Construction Camps and Permanent Townships

"The establishment of construction camps and permanent settlements will result in destruction of some invertebrate habitats. Control of malaria vectors, ticks and other nuisance species will involve the dispersal of pesticides in the vicinity of settlements, and this will have an adverse effect on other invertebrates.

As the area is already settled, some of these effects are already present and the scheme would only intensify them."

3.6 AMPHIBIANS AND REPTILES

3.6.1 Amphibians and Reptiles of Batoka Gorge

The Gorge does not constitute a favourable environment for amphibians and reptiles. The absence of reeds and rushes eliminates most semi-aquatic reptiles and amphibians (Broadley, 1975), and the flushing action of the annual floods is another unfavourable factor. During two days of helicopter flights through the Gorge in October, 1981, only two small Nile Crocodiles were seen.

3.6.2 Impacts of the Batoka Scheme on Reptiles and Amphibians

Overall, the impacts of the scheme are likely to be beneficial rather than adverse. The lake would have few shallow inlets, but in these there should be some development of reeds and rushes (restricted by the seasonal fluctuations in water level) which would favour amphibians. The crocodile population might expand with the slightly more favourable breeding conditions, but could be easily controlled if a threat to recreationalists.

3.7 ORNITHOLOGY

3.7.1 Bird Populations of Batoka Gorge

No ornithological work, apart from a few casual observations, is reported for the Batoka Gorge area. Apart from some birds utilizing the narrow fringe of riparian vegetation at the base of the scree slopes, and some birds nesting on the upper cliffs, few birds are to be seen in the Gorge. Black Storks (Ciconia nigra) and the rare Teita Falcon (Falco fasciinucha) have been known to breed on the upper cliffs of the Gorge. It seems possible that the White-collared Pratincole (Glareola muchalis) might utilize the boulder-

strewn stretches of the Gorge for breeding, but this has not been confirmed.

3.7.2 Impacts of Lake Batoka on Birds

The overall impact of Lake Batoka on birds would be minimal since so few habitats would be flooded. The Teita Falcons breed on high cliffs at the upstream end of the Gorge, near the Victoria Falls, where the change in water-level would make very little difference. Similarly, the creation of the lake would not be likely to affect the breeding of the Black Storks and might, in fact, increase the food supply for them, as well as providing feeding grounds for various birds not presently found in the Gorge. Those few birds that do require the riparian fringe habitat or the rocky river habitat would still find these habitats downstream of the dam.

3.8 MAMMALS

3.8.1 Mammal Populations of Batoka Gorge

The rocky environment of the Gorge does not hold many mammals. The gradients are generally too steep, even if food were available, to attract large mammals other than Chacma Baboons, Vervet Monkeys and Klipspringers. In the surrounding area, which has less precipitous slopes, some Eland, Sable, Kudu and Waterbuck may be found, together with smaller species, although the antelope suffer from the depredations of local tribespeople. The river within the Gorge supports a population of Clawless Otters, which must somehow survive the floods. No Hippopotami live here.

3.8.2 Impacts of the Batoka Scheme on Large Mammals

The creation of Lake Batoka would probably benefit the mammal population since it would make access to water somewhat easier, and it would leave adequate amounts of rocky cliff habitat for those species that frequent this. The Clawless Otters would find a very favourable habitat with the lake since the hazard of annual flooding would not arise

and fish stocks should be greater than in the river. A couple of Hippopotami might find their way to the lake, where they could live in the shallower inlets and could graze on the small amounts of shoreline grass provided their numbers did not increase. It would be desirable to designate a strip of land on the Zimbabwean shore of Lake Batoka as a Recreational Park in order to allow game numbers to build up (with restocking, if necessary) thus enhancing the attraction of the lake for tourists.

3.9 RIVER FLOW

3.9.1 The Flow Regime of the Zambezi in Batoka Gorge

The Zambezi within Batoka Gorge presents a spectacular sight in both the wet and the dry seasons. In the wet season, the river rushes through the deep cleft in the basalt as a foaming torrent, and in the dry season it swirls along a narrow channel between the black fissured outcrops and scree banks that are then exposed. The process of wearing its channel into the solid rock has taken the river such a long time that any relatively recent changes in the river flow are of little geomorphological significance. Ecologically too, variations in annual river flow within the Gorge are of far lesser consequence than the variations in annual flow downstream of Kariba. There is no upstream regulation on the Zambezi, so the river flow consists simply of the Upper Catchment runoff; the variations in this runoff since 1924/25 have been discussed previously (2.9.1). The maximum flow is generally in April, while the minimum flow is generally in November. (See Fig.19)

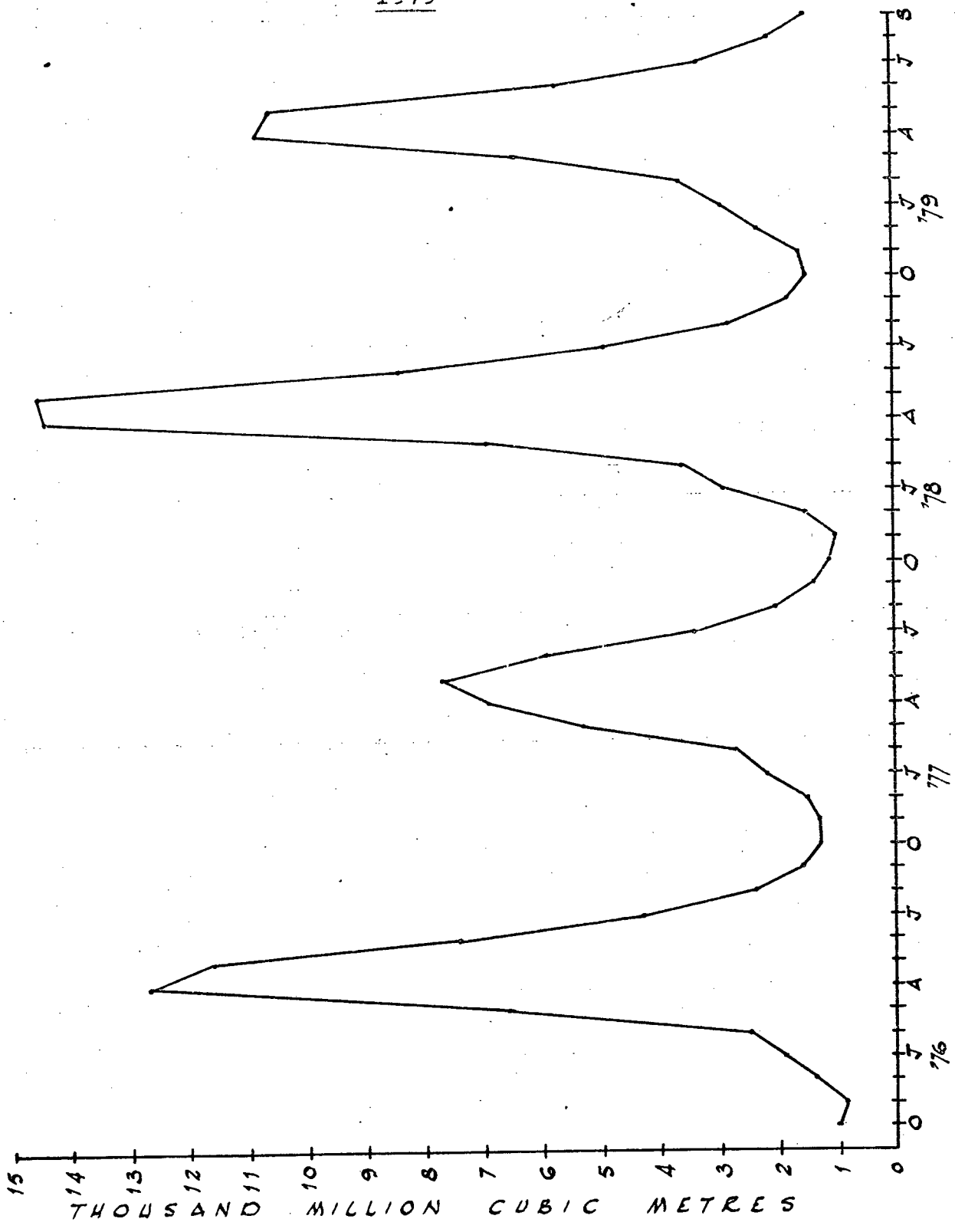
3.9.2 Impacts of the Batoka Scheme on River Flow

The Batoka scheme would be operated in a run-of-river mode. Losses due to evapotranspiration would be insignificant.

> "The total storage capacity of the Batoka reservoir would be less than 2×10^9 m^3, of which only some 20 per cent could reasonably be used as live storage. There is therefore no scope for over-year storage nor even for any significant seasonal regulation.

FIG. 19

UPPER CATCHMENT MONTHLY RUNOFF FROM OCTOBER 1975 TO SEPTEMBER 1979



(Original data from Central African Power Corporation, 1978, 1981.)

However, apart from daily and weekly variation to suit system load, it may be possible to enhance flows during the critical dry months of October and November in certain years." (Merz and McLellan, 1981, Vol.2, 5.34)

TABLE 15

PROJECTED RIVER FLOWS IN BATOKA GORGE (x 10^9 m^3)
(Merz and McLellan, 1981)

	Minimum	Mean	Maximum
Annual flow	22,0	44,3	68,5
Monthly flow	0,5	3,7	20,8

"Due to the small size of the reservoir, it would be necessary to time closure to coincide with minimum river flows i.e. in September, October or November" (this would give maximum time for remaining work on the wall to be completed).

"In an average year, the reservoir would then fill in about 30 days ..... "

3.10 LIMNOLOGY

3.10.1 Physico-Chemical Characteristics of the Zambezi River above Lake Kariba

Physical and chemical conditions of the river vary greatly in obvious accordance with the flow regime. During the high-flow period (about February to June), the flushing effect and large volume inhibit any slight influence that local conditions might have on the water's chemical composition; in general, concentrations of major ions are reduced to one third of their annual maximum values (Balon and Coche, 1974). The conductivity thus varies during the year from about 40 μScm^{-1} (high-flow period) to about 120 μScm^{-1} (low-flow period). In Batoka Gorge, the water is affected little by local conditions even in the low-flow period due to the insolubility and reduced release of minerals from the basalt rock, and to the lack of biotic influences, relative to other sections of the Zambezi.

The maximum water temperature (not exceeding 30° C) is thought to be reached in January, as the flow increases, and the minimum (above 15° C) in June-July. The water remains well-oxygenated throughout the year. The Barotse Plains and the Chobe Swamp act as sediment traps so that the water passing over the Victoria Falls carries a relatively light load of silt. Most silt is carried when the river flow is high, so the depth of visibility is at its minimum when the flow is at its maximum.

TABLE 16

SOME MEASUREMENTS OF BATOKA GORGE WATER, OCTOBER 1981

Conductivity	97 μScm^{-1}
pH	7,8
Temperature	23° C
O_2	9,137 mgl^{-1}
NH_4	0,011 mgl^{-1}
NO_3	0,018 mgl^{-1}
PO_4	0,010 mgl^{-1}

3.10.2 The Limnology of Lake Batoka

(Information derived from the contribution of Magadza and Fair, 1981, and Marshall, 1982)

The surface area of Lake Batoka (about 20 km^2) would be comparable with that of Lake McIlwaine (near Salisbury) but Lake Batoka would have 7 times the volume and 160 times the annual inflow. These features would make it a unique lake in Africa, being possibly closer to the Kafue Gorge reservoir than any other. Perhaps the most important aspect of Lake Batoka would be the rapid throughflow of water; its replacement time has been estimated at 15 days, and in peak-flow periods this could be as low as 3 days. This means that the reservoir could only stratify for very short periods (with the thermocline near the surface) when inflow is at its lowest, and it would be unlikely to develop a deoxygenated hypolimnion as there would be little accumulated organic matter on the bottom, and the presence of the world's largest waterfall at its head means that the incoming water would be thoroughly oxygenated.

At the height of the Zambezi's annual flooding, the flow velocity in the reservoir might be in the order of 20 km per day and turbulent mixing would occur. The rapid throughflow of water would inhibit the development of plankton populations, except possibly in the late dry season (plankton populations may be limited further if extensive weed mats reduce light penetration).

The mean conductivity of Lake Batoka is estimated to be about 80 μScm^{-1}. Assuming an average depth of about 70 m, this gives the reservoir a morphoedaphic index (see 2.10.2) of 1,1.

3.11 AQUATIC VEGETATION

3.11.1 Aquatic Vegetation of Batoka Gorge

The rocky walls, swift water and variable water-level at Batoka Gorge are not conducive to the development of aquatic vegetation. A few riverbank plants, such as Phragmites reeds and Cyperaceae, are able to grow on small pockets of alluvium in a few places where the force of the flooding water is reduced and a supply of seepage water is available throughout the year.

3.11.2 Aquatic Vegetation of Lake Batoka

(Information derived largely from the contribution of Magadza and Fair, 1981, and Marshall, 1982)

Rooted aquatic macrophytes are unlikely to grow along the shoreline of Lake Batoka, except in a few inlets, due to the steep, rocky sides and likely fluctuation in water-level. However, floating aquatic weeds would be most important. Salvinia molesta (Kariba Weed) could assume nuisance proportions, especially in the rather dendritic eastern portion of the lake. Cyperus papyrus could also establish itself, forming rafts, as it is often carried over Victoria Falls from the upper Zambezi. Vossia cuspidata may similarly form rafts; this grass is well-established in Devils Gorge. Eichhornia crassipes (Water Hyacinth) and Pistia stratiotes (Water Lettuce) are unlikely to be troublesome on Lake Batoka as they would be on Lake Mupata, due to the lower

nutrient status of the former reservoir. Besides, Eichhornia has not yet been recorded in the upper-Zambezi.

Salvinia has been steadily colonizing the open waters of the Okavango Swamps, despite a nutrient status not significantly higher than that of the Zambezi River (Seaman et al., 1978; Mitchell, 1970) and at Lake Batoka the rapid throughflow of water would certainly maintain adequate levels of nutrients for Salvinia to spread, possibly over the entire surface of the lake. Wind and wave action on Lake Batoka is likely to be minimal due to the restricted surface area and winding form of the reservoir, so weed mats would cohere. During the flood period the water might move in a current of 20 km per day, which would tend to pack floating weed mats above the dam wall. On the Kafue Gorge reservoir it was found necessary to use explosives to dislodge such compacted weed mats.

The possible influence of invertebrates in controlling the floating weeds (as discussed in relation to Lake Mupata) is a debatable issue. Spraying of herbicides might be a feasible control strategy over some parts of the reservoir, and floating booms across the narrow stretches might be used to keep the weed mats out of the cleared parts. Consideration should be given to the design of the floodgates, since the spillage of water from the top of the reservoir would remove large quantities of weeds. Possibly the saddle-dam that is to be built just to the south of the main wall could incorporate the appropriate type of floodgates. With such steep sides, drawdown of Lake Batoka would not strand a significant quantity of floating weeds, although the fissures in the basalt might trap a small amount. If the weeds are to be controlled, removal of mats should commence as they first develop to prevent the invasive species from becoming established.

Although a hindrance to human activities, the floating macrophytes would be useful in the aquatic ecology since they would retain nutrients within the reservoir, they would provide invertebrate and bird habitats on the lake surface and

along the shoreline (when stranded), they would afford protection for small fish and they might help provide a substrate for the development of vegetation along the inhospitable shoreline. With the absence of semi-submerged trees, and with the deep water and reduced wave action, it would be fairly easy to harvest water weeds and to lift them out of the Gorge with elevators, cranes or pumps. Aquatic macrophytes such as Salvinia have been shown to be of use in the production of biogas and fertilizer (Anon., 1976). The Kalahari sands around Batoka Gorge could be much improved for agriculture through the addition of compost made from harvested water weeds.

3.12 ICHTHYOLOGY

3.12.1 The Fish of Batoka Gorge

With the Victoria Falls acting as a unique zoogeographical barrier, the fish species composition of the swift waters in Batoka Gorge is different to that of the wide, shallow river above the Falls, although there is a faint possibility that some of the smaller species might be able to survive the drop of 90-95 m. The fish fauna occurring in the inhospitable aquatic environment below the Falls is probably limited in diversity to less than half the species found above the Falls, and is thought to be similar to that of the stilling pool below Kariba Dam. Species that are characteristic of these turbulent Zambezi waters are the squeakers (Synodontis spp.), the rock catlets (Chiliglanis spp.) and the Red-eye Labeo (Labeo cylindricus). The inaccessability of the Zambezi in the Gorge and its low stocks of fish reduce its attraction for fishermen, although in October, 1981, several temporary fishermen's huts and smoking racks were observed on the Zambian bank in the vicinity of the Chibonga River. During the high-flow period, fishing in the Gorge would be impossible.

3.12.2 The Fish of Lake Batoka

(Information derived from the contribution of Marshall, 1982)

Lake Batoka would be dominated by riverine species, including

fishes with sporting or commercial value, such as Hetero-branchus longifilis (Vundu), Distichodus spp. (Nkupe and Chessa) and Labeo congoro (Purple Mudsucker). The Tiger-fish (Hydrocynus vittatus) would be the main predator. The cichlids (tilapias) would be much less abundant except perhaps in some localities where inflowing streams might provide suitable habitats. Several smaller species, that are rare in large reservoirs such as Lake Kariba, would probably thrive in Lake Batoka; these would include Barbus spp., Opsaridion zambezensis, Labeo cylindricus, and Chiloglanis spp. Both Alestes imberi and Alestes lateralis would be likely to occur, although the former would probably be more common as it shows a greater preference for rocky shores and running water.

Plankton populations in Lake Batoka would be so low that the Kapenta Sardine (Limnothrissa miodon) would not prosper. However, it would be recommended that its introduction be attempted since even a small sardine population would be able to utilize the available plankton and so retain nutrients and increase overall fish production. This fish is believed to have played a part in the reduction of Salvinia at Lake Kariba (Marshall and Junor, 1981) and so might do the same at Lake Batoka.

3.12.3 Fishery Potential of Lake Batoka

(Information derived from the contribution of Marshall, 1982)

The production potential of Lake Batoka is almost impossible to estimate because of the lack of comparative data relating to this type of reservoir. The MEI prediction (see 2.12.3) is that it would yield 15 kg ha^{-1} yr^{-1} (or a total of about 30 tonnes per year). However, this is almost certainly an underestimate since the Sanyati Gorge of Lake Kariba (to which Lake Batoka would be similar, in some respects) has yielded up to 42 kg ha^{-1} yr^{-1} from angling alone (Langerman, 1981), although admittedly yields from the Sanyati Gorge may be enhanced by fish movement from the main lake.

The most important development at Lake Batoka may be that of a sport fishery. The lake would have excellent line fishing

and would be popular for spear fishing because of the deep clear water and lack of crocodiles. Such sport fisheries are rare in Africa (Willoughby, 1979). It has been estimated that one tonne of fish taken at a recent Kariba International Tigerfish Tournament cost ₰40 000 in various expenditures; thus a sport fishery may generate considerable secondary economic activity. As it would be sited in close proximity to the major tourist centre of Victoria Falls, a sport fishery at Lake Batoka would be of great value to the tourist industry.

Lake Batoka would be reached more easily than the Zambezi within the Gorge and would contain a greater stock of fish so subsistance angling would become important to the local people. A small-scale gill-net fishery could also be established; if this yielded 15-20 tonnes per year it would support several families, or supplement the incomes of many more. Fish poaching could be fairly easily controlled due to the small size of the lake and the paucity of outlets.

3.13 HUMAN HEALTH

3.13.1 The Current Health Situation in the Batoka Gorge Area

The general health status of the tribal population living immediately to the south of Batoka Gorge is poor. These people were translocated to this area from other parts of Matabeleland and have never reorganized fully after the move (Dr. L. Westwater, Deputy Secretary for Health, pers. comm.). They suffer from malnutrition, despite previous food aid programmes, as well as from hyperendemic malaria and schistosomiasis. Measles, tuberculosis, leprosy and scabies occur at higher levels among these people than in most other tribal populations. Tsetse fly are absent from the Batoka Gorge area and therefore trypanosomiasis is not a problem. Health services in the area are scanty, consisting essentially of a clinic at Victoria Falls and a mine hospital at Wankie.

3.13.2 Impacts of the Batoka Scheme on Human Health

Impacts Related to the Creation of a Water-Body

Much of what has been written on the health aspects of Lake Mupata (2.13.2) also applies to Lake Batoka. Again, malaria and schistosomiasis would be important diseases to be reckoned with. Although there would be a far lesser amount of rooted macrophytes growing around the shoreline of Lake Batoka, mats of floating weeds on the lake surface would support schistosome-carrying snail populations. Snails of the genus Biomphalaria, carrying Schistosoma mansoni, would prosper on the algae growing on rock surfaces. A policy of maximum lake-level fluctuation, which would facilitate the control of snails, should be possible. Although Lake Batoka would have a small surface area, it is not thought that wholesale application of chemicals to kill snails and mosquitoes would be a practical proposition, due to the high cost of this method of control. However, from the point of disease control, it is fortunate that the shoreline of the lake would be so inaccessible; contact between man and water would be concentrated in a limited number of localities, where spraying of chemicals might be worth trying, and problems of contamination of the water by human waste are likely to be reduced.

Filarial diseases, leishmaniasis and diseases due to arboviruses are all possibilities at Batoka Gorge. Filariasis due to Dipetalonema perstans is most prevalent in dense forests such as Baikiaea and Pterocarpus forests, especially on Kalahari sands, and a major focus of this disease exists in the Lupane/Gwaai area, which is not far from the Gorge. As previously mentioned, this disease might be spread by construction workers, but only develops after a prolonged period of exposure and is not lethal. The environment of the Gorge, with well-oxygenated water flowing swiftly over rock surfaces, would seem to be ideal for the breeding of black flies (Simulidae), which are the vectors of onchocerciasis (river blindness). This filarial disease is a serious problem in nearby countries such as Zaire, but for some reason the man-biting vectors are not found in Zimbabwe, although non-vector species of Simulium have been found breeding along the Zambezi. It is not impossible that the vector and the parasite (Onchocerca volvulus) could somehow

spread to Batoka Gorge in the future, but the reservoir would flood out much of the potential breeding area.

The only case of Marburg's viral haemorrhagic disease reported in Zimbabwe is thought to have been contracted on the main Victoria Falls-Wankie road, so with or without Lake Batoka such viral diseases may occur in the area.

Impacts Associated with the Construction and Operation of the Batoka Scheme

The health problem associated with the construction of the dam wall, power stations etc., would be similar to those experienced at Kariba and those that would be anticipated at Mupata Gorge. A full range of hospital facilities would have to be provided on-site since there are inadequate facilities in the area even for current requirements. The local people would benefit greatly from additional health facilities, as well as from the employment opportunities that would stem from the scheme, and from the supply of fish that would become available. The fact that there is a long stretch of swift flowing river between the dam site and the nearest populated area on the riverbank (over 60 km, to the Matetsi mouth) means that downstream contamination by human waste from the labour force would not be as important a consideration as at Mupata Gorge.

3.14 ARCHAEOLOGY AND ETHNOGRAPHY

3.14.1 Human History in the Victoria Falls Area

(Information derived from Clark, 1952, 1975, and Vogel, 1975)

In the vicinity of the Victoria Falls, there exists a record of man's presence right back to the earliest cultural tradition of which we have evidence. Prior to the formation of the Gorge, the Zambezi flowed towards the Matetsi Valley through a wide, shallow trough in which it left various deposits of gravel. These deposits contain humanoid stone tools which may be in the order of two million years old, as well as a variety of tools from succeeding cultural traditions. The earliest people living along the banks of the upper-

Zambezi of whom we have any other than purely archaeological records are Bushman hunter-gatherers. With the southward movement of the Bantu people (discussed in 2.14.1), the Bushmen were joined by ancestors of the Tonga-Ila (now split into various groups throughout the Zambezi region) who brought with them a knowledge of iron-working and changed the hunter-gatherer subsistence base to an agricultural base. Recent tribal history is somewhat confusing, with a series of wars in the eighteenth and nineteenth centuries resulting in shifts of power between the various settled groups, and with invading Matabele under Mzilikazi further disrupting the situation. This history is outlined by Mubitana (1975).

The physical presence of Europeans in this part of Central Africa extends back for only a century and a quarter, but the indirect effects of foreign activities, such as Portuguese trading downriver, had been felt for many hundreds of years previously. In 1855 Livingstone named the Falls in honour of his Queen, but it is not absolutely certain that he was the first European to visit them. The "Cape-to-Cairo" railway reached the Falls in 1904 and the bridge was completed in 1905. The town of Livingstone, that was then established, owed its growth to the fact that it was a major point of entry to Northern Rhodesia and to its proximity to the Falls. It remained the capital of Northern Rhodesia until 1935. The Zimbabwean town of Victoria Falls has now become the dominant tourist centre.

3.14.2 The Loss of Places of Religious, Historical or Archaeological Significance due to the Batoka Scheme

The Stone Age tools that are found just downstream of the Falls lie in gravel deposits that are left on the flat basalt spurs round which the river now zigzags. Since the lake-level would be so low in the Gorge, it is most unlikely that any archaeological sites would be inundated, nor is it believed that any sites of religious or historical significance would be lost.

3.15 RECREATION AND TOURISM

3.15.1 The Attraction of Batoka Gorge

The deep, zigzag chasm contributes to the overall magnificence of the Victoria Falls. On the Zambian side, several access roads have been built to vantage sites but on the Zimbabwean side such access is not provided and uncleared minefields make walking too dangerous. It is understood that tourists are able to descend to the bottom of the Gorge at the Zambian power station. During 1981, considerable publicity was given to "white-water rafting" in the Gorge. This new sport is promoted by Sobek, an international organization that arranges adventure tours, and is said to promise a "boom for the Victoria Falls tourist industry" (The Herald, 21st December, 1981). Clients cling to rubber rafts that are carried along in the current from the Boiling Pot below the Falls to the Songwe Gorge, or further down-river. Such trips are only possible when the river is fairly low. In view of the fact that this kind of sport appeals to only a limited number of people, it seems most unlikely that it will overshadow the basic attractions of the Falls and greatly expand the tourist trade, but it is clear that the wild environment within the Gorge is a prime locality for adventure-type recreation.

3.15.2 The Attraction of Lake Batoka

Lake Batoka would be a very scenic lake, deep and winding, with seasonal waterfalls splashing down the sheer rock cliffs, the world's largest waterfall near one end and a massive concrete arch wall at the other. Its proximity to the well-developed tourist centre of Victoria Falls would enable its potential for water-based recreation to be fully exploited. The narrowness of the Gorge would necessitate high standards of safety on the part of power-boat operators. Both line- and spear-fishing would be good. A drawback would be the difficulty of gaining access from the lip of the Gorge due to the steepness of the walls, and clearance of anti-personnel mines would be a priority on the Zimbabwean side. Operators of non-hunting safaris feel that Lake Batoka might induce foreign tourists to remain in the Victoria Falls for a few

more days than they would at present, leading to a considerable increase in the revenue that could be derived from tourism in Zimbabwe.

If Lake Batoka were to be created, the tourist authorities would have to make a well-considered decision on the type of development that would be permitted. The lake could be a tranquil wilderness for nature-lovers (including wealthy tourists wishing to "get away from it all"), or it could be a playground of speedboats, casinos, paddle-steamers and other features to promote mass tourism. There may be a lot of merit in the development of a "sacrifice area" that would satisfy the recreational requirements of many people and would relieve the tourist pressure on other areas. A major advantage that is seen in Lake Batoka is that it would draw tourists away from the rainforest at the Falls, which can only absorb a limited number of people at one time without suffering ecological degredation.

The creation of the lake would not entail the complete loss of potential for white-water rafting. It is believed that the headwaters of the lake would extend only to the fifth gorge below the Falls (Merz and McLellan, 1981) so there would still be several kilometres of suitable white-water upstream of the lake; downstream, rapids would still exist for over 50 km. The loss of some potential for white-water rafting is seen as the only real socio-economic objection to the creation of Lake Batoka.

3.16 MAN-MADE STRUCTURES AND COMMUNICATIONS

3.16.1 Man-made Structures and Communications in the Batoka Gorge Area

The area is very undeveloped; there is an all-weather gravel road connecting Deka with the tarred Wankie-Victoria Falls road, and a recently constructed gravel road branches off from this to the dam site. There are no buildings or structures of any kind within the Gorge apart from the Zambian power station at Victoria Falls.

3.16.2 Impacts of the Batoka Scheme on Man-made Structures and Communications

The creation of Lake Batoka would not have any adverse effects on human structures since a retention level has been chosen that would not interfere with the operation of the Victoria Falls power station. The dam would provide an additional road crossing to Zambia, which would be of little significance in view of the existing route via Victoria Falls. Water transport would be advantageous only to tourists and fishermen.

4 GENERAL CONSIDERATIONS

4.1 REGIONAL DEVELOPMENT

Since the Valley consists of National Parks Estate, and has relatively little potential for either mining or agriculture, it is unlikely that the Mupata scheme would stimulate the development of these industries through the provision of power, water and communications. Commercial fishing might entail the establishment of a couple of harbours with processing facilities, but these would not be likely to form growth-points. During the most labour-intensive stage of construction of the wall and south bank complex at Kariba about 8 000 skilled and semi-skilled workers were kept in employment. With increased labour costs, the work force at Mupata Gorge would be smaller. The creation of such jobs at the dam site would obviously be a transient benefit since the completed power scheme would require only a relatively small staff.

In the adjacent Dande communal area, a development plan presently being produced (Hawkins Associates) shows that mining potential, though not assessed in detail, is unlikely to be significant, and agricultural development is constrained by tsetse fly, lack of water, and unsuitable soil types apart from some colluvial and alluvial deposits at the base of the Escarpment and along the major rivers. The Mupata scheme would have a beneficial effect on this area through its provision of power (required especially for irrigation at Mashumbi Pools and Mzarabani) and, to a lesser extent, through the upgrading of an access road. The Dande development study emphasizes the long-term prospects for tourism at the more scenic localities, which are of little use for other economic activities anyway. It seems, in fact, that the optimum development strategy for the Valley and much of the Dande area might centre on the sustained utilization of wildlife resources through tourism and safari hunting. Economic justification for this belief is given by the known returns to the Zimbabwean Treasury and district councils from wildlife utilization in 1981; the Sapi Safari Area, for instance, returned a total of Z$118 598,00 through various fees associated with hunting, in addition to what the professional hunters earned. With the paucity of regional resources other than wildlife, the reduction in tourism/hunting potential due to the Mupata scheme acquires added

significance.

In contrast to the Mupata scheme, a lake in Batoka Gorge would stimulate Zimbabwe's tourist industry. The impoverished population living to the south of the Gorge would enjoy greater employment opportunities with the expanded tourist trade, and there would be a slight hope for increased agricultural productivity due to the provision of water and possibly organic matter from the lake. Since the dam wall would be so much larger than that proposed for the Mupata scheme, its construction would provide more employment.

Some consideration has been given to the possibility of diverting water from Lake Batoka to supply Wankie mines and power stations. There is a drop of 40 m or more between the normal retention level of the lake and the level of land around Wankie Colliery. At present, Wankie is supplied by water pumped along a 44 km pipeline from Deka, on the Zambezi. To the south of the Batoka dam site is a linear valley (along a joint) at the head of which a saddle dam would be built to prevent the reservoir from overflowing. It would be technically feasible to run a large pipeline from this saddle dam north-eastwards down the valley, eastwards along the Gorge and then southwards across the Matetsi valley to Wankie. An alternative would be to pump water out of the lake to a reservoir on the high ground to the south and then to pipe it under gravity to Wankie. Either way, it appears that the distances involved and the difficulty of laying pipelines in the rugged terrain would probably make a Lake Batoka-Wankie pipeline uneconomic.

It is evident that two major factors required for the socio-economic development of an area are potential for primary industry and proximity to the national infrastructure. Both the proposed hydro-electric schemes would be sited in areas which suffer somewhat from the lack of these factors. The Mupata scheme would have some advantage in its commercial fishery and the Batoka scheme would have some advantage in its scenic attributes and location so close to a major tourist centre, but overall it is unlikely that either scheme would stimulate much regional development; Zimbabwe's cities would derive the real benefit, in the form of electricity.

4.2 ZAMBIAN INTERESTS

In July, 1981, the compiler of this report and Mr. M.J. Stanning (economist) visited Lusaka, Zambia, to ascertain the Zambian viewpoint regarding the proposed hydro-electric schemes. Discussions were held with senior Government officials in the Ministry of Lands and Natural Resources and the Ministry of Tourism, with the General Manager of the Zambian Electricity Supply Corporation, with University authorities, with executive members of the Wildlife Conservation Society and with private safari operators (both hunters and non-hunters). The general impression that was gained was that Zambians are very concerned about the possible consequences of the Mupata scheme, although they had few details of this scheme, and knew virtually nothing about the Batoka scheme.

A very large area on the Zambian side of the Zambezi River, opposite the Mana Pools, Sapi and Chewore areas, had been designated as the International Game Park in 1973 but was not developed due to the Rhodesian War. This park was to be used by American operators (Wildlife Conservation International) for safari tourism. The area is to be re-gazetted as the Lower Zambezi National Park, and as soon as landmines have been cleared at least three tourist organizations wish to operate in the area; however, development plans have been delayed pending a decision on the Mupata scheme. The status of wild animal populations in this area is good, despite poaching (the Zimbabwean Department of National Parks and Wildlife Management extends its aerial census surveys to cover part of the Zambian side of the Valley). Private tour operators emphasized the great advantage that the park had in its proximity to Lusaka, and felt that it compared very favourably with the Luangwa Valley as an attraction for international tourists. The General Manager of Zambia Tours and Lodges, a parastatal organization, said that tourism had been given third priority for development in Zambia, after mining and agriculture, and that the Lower Zambezi National Park would receive first consideration for new tourist facilities if the future of its riverine section could be guaranteed for a reasonable period. Tourist facilities were already being developed at the Kafue-Zambezi confluence; it was apparently not realized that these might be

flooded. Zambia has a diversity of water bodies for recreation and Lake Mupata would therefore not be much of a tourist attraction.

Apart from the loss of tourism potential, another objection to the Mupata scheme was the likelihood that it would inundate sites of historical and archaeological interest, which are being investigated by the Zambian Museum and Ministry of Culture. Also, there would be the problem of resettling the Zambian peasants living along the river between Kariba Gorge and the game park. Apparently some people around the Kafue confluence and further upstream on the Zambezi had been moved in from the area that was flooded by Lake Kariba, and still felt strong resentment at their forced translocation (which involved some bloodshed); another move could provoke political unrest, in addition to the great expense, logistic problems and social upheaval.

Due to their lack of knowledge of the Batoka scheme, the Zambians were unable to make any assessment of its likely effects on Zambian interests; the only reservation that was voiced related to the possible loss of potential for white-water rafting.

The General Manager of the Zambian Electricity Supply Corporation said that electricity demand in Zambia would rise due to factors such as railway electrification, the development of irrigation schemes, expanding fertiliser production and refrigeration of deep shafts of copper mines (over 60 per cent of electricity is used on the Copperbelt). However, Zambia has sufficient installed generating capacity to meet its electricity requirements for up to ten years, or more, and when new plant was required, in addition to the likely extension on Kariba's north bank, the Kafue Lower scheme would be the best option (200 m head below the present Kafue Gorge station could be utilized to give an installed capacity of 450 MW). Thus it may not be in Zambia's interests to participate in either of the proposed Zambezi schemes for many years to come.

An official Zambian committee to consider the environmental

implications of the Zambezi schemes is likely to be established under the joint auspices of the Ministry of Lands and Natural Resources and the Ministry of Power, Transport and Telecommunications. Once this has been established, some research might be undertaken on the Zambian side, although this would probably depend on outside funding. The Kafue Basin Research Committee, consisting essentially of University staff, is prepared to expand its field of interest to cover the Zambezi schemes, but its own financial and manpower resources would not be adequate for an Environmental Impact Assessment.

4.3 CONSERVATION

4.3.1 Development and Conservation

(Information on genetic conservation derived from the contribution of Attwell, 1981)

Leopold (1953) states that the first rule of intelligent tampering is to save all the pieces. In debating new development proposals, conservationists and developers should seek the kind of creative compromise that respects the need to conserve all components of the ecosystem as well as the need to utilize natural resources. Man is dependent on the interlinked components of the natural world in ways that he is still discovering; ecosystem alterations may entail unwelcome and irreversible effects if the abiotic base is changed drastically and/or if too many biotic components are lost (Stauth, 1980). It is often impossible to say beforehand whether or not "too much" will be lost as a result of a particular course of action since the natural world operates in a synergistic fashion and its balances tip suddenly and unexpectedly.

Part of the rationale for environmental conservation relates to practical considerations of genetics. The World Conservation Strategy (International Union for Conservation of Nature and Natural Resources, 1980) promotes, as one of its three main aims, the preservation of genetic diversity "on which depend the breeding programmes necessary for the protection and improvement of cultivated plants, domesticated

animals and microorganisms, as well as much scientific and medical advance, technical innovation, and the security of many industries that use living resources." (p. VI).

The preservation of genetic diversity is currently viewed as a matter of insurance and investment : the continued existence of wild varieties of plants of economic value is humanity's insurance against the destruction of the domesticated forms, and might enable the development of additional useful varieties in the future. The genetic diversity that is reflected in modern agriculture is very limited. For instance, only four varieties of wheat produce 75 per cent of the crop grown on the Canadian prairies, an extremely vulnerable position in terms of plant pests and diseases. In the medical field, the availability of a diversity of natural products is of paramount importance. Many plants contain chemicals of medicinal value, and the complexity of these compounds often means that they would be difficult (and costly) to synthesize (Everett, 1979). More than 40 per cent of prescriptions issued each year in the United States of America contain a drug of natural origin (Farnsworth and Morris, 1976). This is despite the fact that only a very small percentage of plant species has been investigated for medicinal components. Not only are wild plant gene pools essential for man, but equivalent justification can also be advanced for the preservation of animal "reservoirs". For example, the introduction of dung-beetles into Australia aided in problems arising from the prolific droppings of that country's 20 million cattle (Lee, 1979).

The importance of genetic resources increases concern over the fact that this century will see the end of significant evolution of large plants and terrestrial vertebrates in the tropics (Soule, 1980). Tropical reserves are too small for allopatric speciation of these organisms to occur within them, and it is unrealistic to hope that between-reserve isolation could substitute for within-reserve isolation, as island biogeographic evidence suggests an extinction rate high enough to ensure that speciation will be suppressed (Soule, Wilcox and Holtby, 1979).

The loss of genetic resources will be minimized if governments perceive conservation as the preservation or creation of diversity in ecosystems (Dasmann, 1968). Developing countries should keep options open for the future by preserving their remaining near-natural biotic communities for as long as possible, however "worthless" these communities may seem. Proposed projects must be evaluated not only in terms of economic criteria but also in terms of conservation criteria relating to ecosystem structure and diversity to ensure that the "least-costly"alternative is in fact chosen.

4.3.2 Conservation of Zambezi Ecosystems

The Zambezi is the fourth largest of the river systems in Africa, after the Nile, Zaire and Niger. It is the least developed of the four systems in terms of human settlement and, apart from the Niger, is the only one with areas of protected status along its banks (Barkham, 1981). The inadequate conservation of major river systems in Africa gives considerable importance to these protected areas.

The middle-Zambezi, extending from Victoria Falls to Cabora Bassa Gorge, consists essentially of man-made lakes (along two-thirds of the distance), gorges (Batoka, Devils, Kariba and Mupata) and the "sandbank" river section in the Valley. The *Acacia* alluvial woodland fringing this latter section is a very valuable community in terms of national ecosystem/species conservation in Zimbabwe. Cumming (1981) has derived the following figures relating to *Acacia* alluvial woodland in Zimbabwe:

Total area	=	2 080 km^2 ;
Protected area	=	380 km^2 ;
Protected area north of watershed	=	270 km^2 ;
Middle-Zambezi (Mana Pools) area	=	120 km^2 .

The *Acacia* alluvial woodlands north of the watershed differ considerably in species composition from those in the south, and representative areas of both should be conserved (Muller and Pope, 1982); many species occur in these types which are not found, or are uncommon, in other vegetation types. The middle-Zambezi *Acacia* woodlands are the prime example of the

northern type since they are extensive and they are rich in the alluvial plant species (with various vegetation sub-types due to the variability of the alluvia on which they have developed). Also, these woodlands are the least disturbed by anthropogenic influences (Cumming, 1981).

The following woody plant species occur only in the Valley, mainly below the proposed floodline, and would be pushed towards extinction in Zimbabwe if Mupata Dam were to be built: Strophanthus courmantii, Cassine schlechterana, Ficus zambesiaca, and Cassipourea gassweileri (Muller and Pope, 1982). With regard to genetic conservation, it is worth considering that Cassine schlechterana is a rare member of the family Celastraceae, some of whose other members have been shown to contain alkaloids with pharmacological properties, and the medical importance of this particular species has yet to be assessed (Muller, in Attwell, 1981). Strophanthus courmantii (Apocynaceae) also has a relative of importance to medicine, S. kombe (in demand for the treatment of cardiac disease). Not only would S. courmontii be eliminated in Zimbabwe were the Mupata Dam to be constructed, but resultant increased animal pressure on the jesse thickets might decrease the abundance of S. kombe (Attwell, 1981).

Acacia albida, the dominant tree of the alluvial woodlands, has been of some significance in traditional African agriculture. This tree is an early colonizer of loose sands and greatly improves the fertility of these sands through the addition of nitrogen and organic matter. It has long been realized that crops grown under A. albida trees will be more successful than those grown elsewhere; the Sultans of Zinder (Niger) promulgated an edict that anyone who chopped a branch off the tree had his arm chopped off, and anyone who felled the tree was beheaded. Consideration has been given to the introduction of A. albida to Northern Australia for agricultural purposes (undated report, School of Environmental and Life Sciences, Murdoch University). A. albida is widespread throughout Africa, but its value to man emphasizes the fact that the vegetation that would be inundated by Lake Mupata is not "worthless bush". The

riparian vegetation that would remain along the Rukomeche River has less well-developed sub-types than the Mana Pools alluvial woodlands, and is much degraded in places due to past cultivation. With the loss of the Mana Pools A. albida woodlands, the Rukomeche woodlands would come under severe browsing pressure.

With regard to animals, the Valley contains some birds and mammals that are rare in other places. An example is the Black Rhinoceros. Although the lake would not inundate important habitat for this particular species, the scheme as a whole (with its associated human pressure) would cause a further reduction in the viability of the wild populations.

The creation of Lake Mupata would diminish environmental diversity; it would mean another Lake Kariba, another Lake Cabora Bassa. A reservoir in Batoka Gorge would be very different. The vegetation that would be lost here is of far lesser significance in terms of species diversity than are the Acacia alluvial woodlands of the Valley. As far as can be ascertained after a very brief survey, no plants or animals would be threatened with local extinction, and the basalt gorge habitat would remain downstream of the dam with virtually the same flooding regime as before (until the construction of the Devils Gorge dam?). Thus there is little that can be said against this lake from the conservation point of view, and in fact the unique lake might be an example of the enhancement of the ecosystem diversity of a nation.

Considerations of ecosystem/species conservation often appear rather nebulous, but one straightforward consideration is that of the ratio between area lost through a hydro-electric scheme and power gained. Goodland (1979) gives a table of such ratios, ranging from the Paulo Anfonso project in Brazil (1 299 MW, 7 520 ha inundated) with a ratio of 173 kW : 1 ha, to the Brokopondo project in Suriname (30 MW, 150 000 ha inundated) with a ratio of 0,2 kW : 1 ha. The Mupata scheme (1 200 MW, 123 000 ha inundated) would have a ratio of 10 kW : 1 ha, whereas the Batoka scheme (1 600 MW, 2 000 ha inundated) would have a ratio of 800 kW : 1 ha.

4.3.3 International Concern

Concern has been expressed by various international conservation bodies over the threat posed by the Mupata scheme to the wildlife of the Valley. The Director-General of the International Union for Conservation of Nature and Natural Resources visited Mana Pools in 1981, and later wrote a letter to the Prime Minister of Zimbabwe, voicing the hope that the project would be evaluated thoroughly. The British Nature Conservancy Council and the New York Zoological Society are also known to have taken an interest in the issue. It appears that Zimbabwe would gain much international prestige if it was seen to give detailed consideration to the environmental implications of development on the Zambezi.

5 CONCLUSION

This report cannot be regarded as a Final Environmental Impact Statement for the following reasons.

i) Information has been gathered over a very short period of time (less than one year), with limited manpower and financial resources. Ecological studies require study-periods that are sufficiently long to cover seasonal and annual variations in the biota.

ii) The areas of study have been very restricted; no work has been done on the Zambian side of the Gorge or Valley, and downstream effects in Mocambique have not been adequately assessed.

iii) Research has been carried out on individual components but it has not been possible, in the time available, to establish the links between the various components through methods of systems analysis. Such analysis is essential since, in an ecological context, the pattern of relations between organisms and their environment should be elucidated and in a broader environmental context it is necessary to discover how human systems interlink with natural systems.

iv) A tentative cost-benefit analysis has been carried out (Stanning, in preparation), but this evaluation exercise had to be based on a very weak foundation of information, and there are obviously many environmental components that cannot be given realistic monetary values. Also, there is a hidden element of subjectivity in cost-benefit methodology; for example, the choice of an appropriate discount rate may be somewhat contentious. It was hoped that the alternative evaluation technique that was developed (du Toit and Stanning, 1981) could capture a cross-section of opinions on the more subjective aspects of the issue of development on the Zambezi, but, again, the lack of time precluded this exercise.

v) Development projects that are proposed to meet a recognized need must be appraised in terms of their alternatives. No work has been done on the broad environmental aspects of thermal power stations in Zimbabwe, so it is impossible to compare the hydro-electric options with these other options.

While it is felt that future work must be carried out in

order to remedy the above deficiencies before a final decision is made on either of the schemes, one broad conclusion can be stated at this stage:

THE CONSTRUCTION OF THE MUPATA GORGE HYDRO-ELECTRIC SCHEME WOULD GIVE RISE TO A COMPLEX SET OF ENVIRONMENTAL IMPACTS, MANY OF WHICH WOULD BE ADVERSE; THE CONSTRUCTION OF THE BATOKA GORGE HYDRO-ELECTRIC SCHEME WOULD LEAD TO A SET OF IMPACTS OF FAR LESSER SIGNIFICANCE TO EITHER NATURAL OR HUMAN SYSTEMS.

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APPENDIX

Articles from Zimbabwe Science News, Vol. 15, No. 5, pp. 112-119, 131.

These are included as elaboration of the proposed methodology of the investigation, although, as explained in 1.5 and 5, the investigation has not yet progressed beyond the information-gathering stage.

ENVIRONMENTAL IMPACT ASSESSMENT IN ZIMBABWE

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THE GROWING controversy over the question of whether or not a new dam should be built on the Zambezi River at Mupata Gorge has focused attention on the procedures of Environmental Impact Assessment (EIA). Whilst there is general recognition of the need for an EIA to be carried out before the final decision is taken, there appears to be some confusion over the actual meaning of this term; also, the status which an EIA would have in the decision-making process has yet to be clarified.

WHAT IS EIA?

The procedures of EIA that are now a mandatory part of development planning in many countries have their origin in the American National Environmental Policy Act (NEPA). This legislation was enacted in 1970 in response to rising public concern for the environment, and requires that all agencies of the Federal Government shall:

> "a) utilize a systematic, interdisciplinary approach which will insure the integrated use of the natural and social sciences and the environmental design arts in planning and in decision making which may have an impact on man's environment;
> b) identify and develop methods and procedures . . . which will insure that presently unquantified amenities and values may be given appropriate consideration in decision making along with economic and technical considerations;
> (c) include in every recommendation or report on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment, a detailed statement by the responsible official on—
>
> i) the environmental impact of the proposed action;
> ii) any adverse environmental effects which cannot be avoided should the proposal be implemented;
> iii) alternatives to the proposed action;
> iv) the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity, and
> v) any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented" (Section 102)

Environmental Impact Assessment refers to the administrative arrangements that are made to promote careful consideration of the environmental implications of major projects or programmes before their construction or implementation, as required by NEPA and other similar legislation. These arrangements must provide for the systematic collection of relevant data for various aspects of the environment (ecological, social, economic and aesthetic aspects), prediction of likely impacts on these aspects, interpretation of the significance of these impacts, communication of the findings to the authorities, and proper integration of the environmental considerations in the planning process at a sufficiently early stage.

METHODS

The identification and interpretation of some likely impacts may be done through rigorous technical analyses whereas the assessment of other impacts may involve subjective value-judgements. Various methods have been developed to provide the framework within which information on these diverse impacts can be drawn together in a meaningful fashion. Most of these methods fall into the following categories.

Ad Hoc

Broad areas of environmental concern are suggested, and educated guesses are made of the likely impacts of a project. The commonest approach here is to hold a round-table workshop of limited duration so that selected experts can pool their ideas. The organisation of these workshops and the format of their written reports vary greatly from one workshop to another.

Checklists

Specific lists of environmental components are presented for investigation of possible impacts. Guidelines may or may not be given on the measurement and interpretation of impacts, and direct cause-effect links between project activities and environmental components are not necessarily revealed. In its simplest form the function of the checklist is basically to prevent the assessors from forgetting about particular potential impacts, but it may also discourage them from thinking about peculiarities beyond the scope of the checklist. The World Bank has devised a checklist for the impact assessments of their projects; however, no indications are given of how to obtain and organise information on the components included on the list.

Matrices

The various activities that are likely to be associated with a particular project are listed along one side of a matrix and environmental components are listed along the perpendicular side. The effect of any activity on any component can thus be indicated in the relevant matrix cell. The matrix suffers from the same disadvantage as the checklist in that it may cause important interactions to be omitted if the list of environmental components is determined *a priori*. Also, there are problems in representing the dynamic nature of interactions (i.e. temporal variations, spatial variations and indirect cause-effect relationships).

Overlays

A set of maps of environmental characteristics (physical, social, ecological, aesthetic) are overlaid to produce a composite characterisation of the regional environment. The optimum location for a particular project can then be established. If the location has already been fixed and/or if the real problem has to do with the type of feature to be constructed, then the applicability of overlay methods is reduced, although they may still be useful in identifying impacted components in a spatial context. Computers are used in the more sophisticated overlay methods.

Modelling

The level of sophistication of modelling methods varies considerably; they may comprise simple network approaches where a diagram is used to trace the series of impacts that might result from each project activity, or they may comprise computer-based simulation models. Various qualitative models have been developed as well as the purely quantitative ones. Although modelling methods have great potential, they require considerable expertise and, being subject to the rule of "garbage in, garbage out", depend heavily on the prior collection of adequate data.

Economic methods

In all the above methods, the "Environment" is given a broad definition and economic aspects are seen as comprising an environmental sub-set. However, economists have developed ways to give monetary values to many environmental components which do not carry market prices, and methods of input-output analysis and cost-benefit analysis are sometimes used in EIA to cover a wide range of likely impacts (Blackie, 1381). These methods assume that the price that can be given to a good is a measure of its relative social value; this is a contentious issue, and the methods are not as objective as they might seem since assumptions have to be made on appropriate discount rates and on "willingness to pay" determinations, but there is no doubt that decision-makers tend to think in money terms.

There is no "best" method to be used in EIA; rather, an approach should be tailored to suit the unique circumstances of each particular project. Obviously, the above methods are not mutually exclusive and, in fact, are commonly fitted together, often in conjunction with methods that are borrowed from other disciplines (such as the Delphi method of business forecasting).

CRITERIA

Experience in America and elsewhere has shown that the choice of an actual method of EIA, and the judgement of the documentary output (Environmental Impact Statement), should be made on the basis of the following criteria (Fuggle, 1980; Jain, 1975).

1. Collection of data for variables relevant to impact prediction

a) Information should be given on the techniques of data production, and any limitations that might be present in the data should be explained.
b) All sources of data should be identified (names and qualifications of investigators should be given).
c) Techniques of data production should be systematic and capable of repetition.
d) Data should be selected to provide the basis for objective rather than subjective measurement of environmental impacts.

2. Analysis and interpretation of impacts

a) The method must encourage a review of the full range of environmental impacts associated with a given project (and relevant alternatives), including secondary or induced impacts. Lateral thinking must be encouraged and tunnel vision prevented.
b) The method must separate project impacts—primary or induced—from environmental changes due to other factors.
c) Impacts should be related to specific environmental components and to specific project activities. One of the advantages of this is that it helps in planning remedial measures.
d) Besides assessment of the magnitude of a likely impact, the significance of that impact (in terms of the overall project and environment) should be assessed.
e) The criteria and assumptions used to determine impact significance should be stated.
f) Location, timing and duration of impacts must be established. Timing relates to the phase of the project during which the impact will occur (construction, operation etc.) and duration refers to the time period over which the impact will occur.
g) An indication of the degree of confidence or uncertainty in impact predictions should be given.
h) Areas of high risk should be identified (i.e. impacts of low probability but high damage or loss potential should be pinpointed).
i) A specific method of comparing alternatives should be provided.
j) The methodology may provide a mechanism for aggregating impacts into a net total or composite estimate. If aggregation is included, specific weighting criteria or processes to be used should be identified (the appropriate degree of aggregation is a hotly-debated issue).
k) A method should allow for the involvement of interested parties and the public in a responsible manner (particularly as regards the interpretation of impact significance).
l) Overall, the method should be free of analyst bias so that broadly the same assessment of a project will be made by different analysts using the same method.

3. Communication of the findings of the study

a) Key issues and impacts should be highlighted.
b) Affected parties should be identified.
c) The project setting should be described to aid decision-makers in developing an adequate overall perspective.
d) The reasons for the development should be outlined. This should not be a superficial statement but should indicate underlying social, economic and land-use goals.
e) An indication should be given of the extent to which remedial measures to minimise negative impacts are possible and are planned.
f) The main arguments and findings of the study should be summarised intelligibly for the general public and its elected representatives, and the report should also provide the additional technical content necessary for other competent specialists to formulate informed views on the subject.

ZIMBABWEAN SITUATION

This country has a proud record of conservation awareness and we should expect rapid realisation of the fact that EIA procedures are not "anti-development", are not merely means of placating emotional, irrational and vociferous animal-lovers but are rather orientated towards ensuring that decision-makers will make a holistic evaluation of a project, rather than looking at a particular resource (such as hydro-electric power) in isolation.

Previously, our legislation empowered the Natural Resources Board to delay or prevent the construction of a dam or conservation work costing in excess of one hundred thousand dollars if this work was expected to cause major damage to the environment. This legislation has recently been amended since it was seen as being potentially obstructive to development and now all that is required is that the Board should make reports on such projects to the Minister of Natural Resources and Water Development. The Natural Resources Board has recently established a Committee to Advise on the Environmental Impact of Major Development Projects (CAMP) and an investigation into the issue of development projects along the Zambezi has been initiated under the auspices of this committee; this investigation will be in line with recognised EIA procedures and will use a combination of the methods outlined previously. In fact, it is hoped that the Zambezi investigation will serve to introduce EIA to this country so that reports that the Natural Resources Board makes on major projects of the future will be in the form of Environmental Impact Statements. In order to give EIA the status in development control that it enjoys in other countries, a mechanism should be introduced to ensure that the environmental considerations that are covered in these reports are necessarily integrated into our decision-making processes and are not just given superficial treatment. Any fear that this might obstruct development should be weighed against the fear of near-sighted planning; there is abundant evidence that good environmental planning makes good economic sense.

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INVESTIGATION OF LIKELY ENVIRONMENTAL IMPACTS OF POSSIBLE PROJECTS ON THE ZAMBEZI RIVER

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THE NATURAL Resources Board has initiated an investigation into the probable environmental consequences of building new hydro-electric schemes on the Zambezi River. This investigation will also cover the likely effects of other development options for the section of the Zambezi Valley between Kariba and the Mocambique border; this area has potential for the development of hunting and tourism, agriculture and possibly mining. The Department of Land Management at the University of Zimbabwe has been tasked with the co-ordination of the investigation, which will be in the form of an Environmental Impact Assessment incorporating a Social Cost-Benefit Analysis. The proposed methodology is outlined in this article.

STEERING COMMITTEE

The Natural Resources Board's Committee to Advise on the Environmental Impact of Major Projects (CAMP) will be responsible for overall guidance of the investigation. This committee includes representatives of various organisations that are involved in the issue.

GEOGRAPHICAL BOUNDARIES

Many of the likely environmental impacts of the projects will have to be viewed in a spatial context, and it is therefore necessary to delimit the geographical areas within which these impacts are to be investigated. Since the Zambezi constitutes a system extending from source to mouth, it is suggested that both upstream and downstream effects should be considered. Due to limitations of time and information availability, it is probably not feasible to investigate likely effects on the Zambian side in much detail in this particular investigation. Between Kariba and the Mocambique border, a sensible southern boundary would be the game fence running above the Zambezi escarpment since this is a precise dividing line between the populated southern areas and the wildlife areas to the north. A clear southern boundary is not so readily apparent for the area south of the stretch of the Zambezi between Victoria Falls and the western end of Lake Kariba (including the Batoka Gorge and Devil's Gorge dam sites); possibly the main Bulawayo-Victoria Falls road would be as good a boundary to use as any.

PROJECT DETAILS

In order to carry out a systematic investigation of the probable environmental effects that would arise from the development options, it is first necessary to obtain a breakdown of all the various activities that are likely to be associated with each project (the Central African Power

Corporation will provide details of proposed dams, and the Department of National Parks and Wildlife Management and the Department of Tourism will provide details of the wildlife development option). The availability of information will probably be restricted to some extent by requirements for confidentiality and by a lack of detailed planning for some of the options. However, it is important that *as much information as possible* on the nature of each activity associated with each option (including location, timing, duration, financial cost, and labour) should be given in order that specialists on various aspects of the environment (ecologists, sociologists, economists) can predict the consequences of each activity within their fields of expertise with the greatest possible accuracy. Any remedial measures that are proposed to reduce the adverse impact of a project activity should also be outlined. Details must be obtained of activities which are likely to occur sometime in the operational stages of projects, in addition to those activities which will take place only in the initial development stages.

Activities would be summarised under headings such as:

Roads and bridges,
Transmission lines,
Blasting and drilling,
Construction camps,
Inundation,
River-flow control,
Resettlement,
Hunting camps,
Walking trails,
Irrigation canals.

Information will also be sought on further actions or policies that are not necesarily part of the proposed projects but which might affect the environment in conjunction with, or apart from, the actual projects' effects e.g. the alignment of a new rail link between Lusaka and Salisbury could be postulated assuming a dam wall to be built at a particular site.

ENVIRONMENTAL COMPONENTS

The 'Environment' can be broken down into multitudes of different aspects, falling into broad categories such as ecological components, social and political components, cultural and aesthetic components, economic components and geophysical components. Obviously, different people have different ideas on the relative importance of these components with regard to the Zambezi issue (this is the crux of the problem of deciding what the 'best' option will be). At this stage of the investigation, all that is required is that a list of *all* the relevant environmental components should be generated.

It is beyond the ability of one person to think of all these components so the ideas of a wide variety of informed people should be incorporated. In order to make a start, the co-ordinators of the investigation will compile a preliminary list largely on the basis of a literature review (with each component clearly defined). Copies of the project details together with the preliminary list of environmental components will be sent to people who are interested in the issue and who are representative of a full range of opinion. These people will be asked to add to this list any further environmental components which they consider to be relevant (even only vaguely relevant) to the development options as outlined. The additional components must be defined. It is not important that all the components should be amenable to quantitative measurement. The lists that are returned to the co-ordinators will be combined to create an expanded list; this will be sent back to the respondents for them to add any more components that might have occurred to them, or for them to delete any components which they consider to be totally absurd. Through this feedback process (which is along the lines of the Delphi technique of business forecasting) a final list of environmental components can be compiled, and the components can then be grouped into categories. Hopefully, all interested parties will be satisfied that the assessment of the development options will be sufficiently comprehensive if it takes all these components into account.

Examples of possible environmental components are:

Primary productivity,
Crustal stability,
Wilderness qualities,
Archaeological sites,
Sport fisheries,
Kariba weed,
Arable land,
Bilharzia,
Black rhinoceros population,
Employment opportunities.

IMPACT STUDIES

For each development option, a checklist of specific project activities will be available and a checklist of environmental components will also be available. These two checklists will be arrayed along perpendicular axes to form a matrix so that each activity can be related to each environmental component (Fig. 1). The empty cells of each matrix will be filled in by specialists who will predict the likely interactions between project activities and environmental components that fall within their respective fields of expertise. These specialists will be local people, from various agencies, who are willing to contribute their expertise to this important investigation. They will identify effects that are likely to occur in the short-term (during and immediately after the construction phase of the dams or within the first few years of the wildlife development and agricultural development options) and in the medium-term when the projects are fully operational and the environment has had some time to recover from the initial effects (twenty-odd years after project initiation). The interactions will be quantified wherever possible e.g. in terms of hectares of arable land lost, percentage decrease in black rhinoceros population, number of jobs created for unskilled labourers. In many cases, only a range of probable values can be postulated for the interactions, and in other cases the interactions will have to be expressed as ratings or rough judgements of 'more' or 'less' etc. It is important that the data appearing in the estimates should be clearly recognised as being 'best estimates' that are not likely to be absolutely accurate (the estimates for the medium-term effects will be even less accurate than those for the short-term effects).

The purposes of matrices are:

(a) to focus attention on interactions between specific project activities and specific environmental components;
(b) to give a visual display that enables a reviewer to gain an impression of the range of impacts resulting from each activity, and to see which environmental components are especially vulnerable; and
(c) to organise data in a fashion that might be amenable to future manipulations such as computer processing.

As well as putting estimates in the cells of the matrices, each specialist will produce written outlines of the impacts which he or she has identified. These reports will consist of brief descriptions covering the short- and medium-term effects in conjunction with classifications of the impacts according to the following matters.

1) The desirability of the impact (beneficial, adverse, uncertain).
2) The significance, or importance, of the impact in terms of the overall project and environment (major, moderate, minor, uncertain). This will be a matter of subjective judgement on the part of the expert.
3) The likelihood of the impact occurring (certain, probable, unlikely, unknown).
4) The finality of the impact i.e. can the environmental component ever be returned to something like its original state after the impact has occurred? (Reversible, irreversible, uncertain).
5) The order of the impact i.e. is the impact the direct result of a project activity affecting an environmental component or is it an induced impact resulting

Fig. 1 Section of Hypothetical Impact Matrix for a Particular Project

Project Activities / Environmental Component	Transmission Lines 01	Roads and Bridges 02	Blasting and Drilling 03	Inundation 04	. . . etc	Overall Project
Arable Land 01 (ha. lost)	-40 -40	-70 -70		-2 200 -2 200		-3 000 -2 800
Historical Sites 02				-3		-3
Black Rhino 03	Severe Slight	Severe Moderate	Severe	-40% pop. -10% pop.		-60% pop. -45% pop.
Aesthetic Value 04	Reduce Reduce	Reduce Reduce	Reduce	Reduce ?		Reduce Reduce
. . . etc						

The upper estimate in each cell corresponds to the short-term effect and the lower estimate to the medium-term effect.

from a previous impact? (Primary, secondary, tertiary or higher).

6) The time of occurrence of the impact (immediate i.e. directly following an activity in the early, or constructional, stage of the project; medium-term i.e. directly after an activity that is scheduled sometime in the operational stage of the project, or a delayed consequence of an activity that occurred in the early stages of the project; long-term i.e. a delayed impact occurring twenty-five years or more after the project has been initiated).

7) The duration of the impact (transient i.e. will be evident only while an activity of short duration is actually taking place; temporary i.e. will still be evident for a few years after an activity has ceased, or will be evident while an activity of several years' duration is taking place; permanent i.e will go on 'forever' in the absence of intervention).

8) The adequacy of available information used to predict the impact (adequate i.e. sufficient information is available to predict the impact with the greatest possible accuracy; inadequate i.e. further information is desirable in order to improve the accuracy of the prediction).

It may prove to be impossible to produce adequate reports on *all* the impacts in the time available, in which case those impacts which are not considered to be important (i.e. those of 'minor significance') need only be classified and not described.

Overall, the impact reports will be written in such a way as to ensure that the criteria that were outlined in the preceding article of this issue of *Science News* are satisfied. Since these impact reports may be somewhat technical, succinct summaries will be written in layman's terms to cover the overall impacts of project activities on categories of environmental components (e.g. the effect of inundation on rare species); also, the current state of the environmental components will be outlined in a non-technical fashion so that the project settings are described.

The information that is gained from these impact studies will comprise the bulk of the Environmental Impact Statement that is produced for the decision-makers and for the interested public. Much of this information will serve as input for the economic analyses.

ECONOMIC ANALYSES

M. J. Blackie's article in the February issue of *Science News* dealt with the applicability of Social Cost-Benefit Analysis (SCBA) in situations involving the development of wilderness areas. Blackie indicated that various problems arise when SCBA is used in these situations to guide the allocation of scarce resources between competing ends: the method fails to recognise opportunity costs foregone by development of wildlands; it does not deal with the irreversibility of investment decisions, and it shows shortsightedness in discounting the benefits of a development project over time. These problems are related to the lack of recognition of the social value that is held by wilderness areas. Recently, some American economists have modified the conventional framework of SCBA in order to cover these deficiencies. SCBA will show inherent bias towards the development rather than the conservation of natural areas if their social value is ignored; hence, the economic analysis that is to be carried out as part of the Zambezi investigation will be based on the American thinking, which attempts to eliminate this bias.

Before describing the methods that are to be used, it is necessary to explain the economist's general approach to the valuation of natural areas. Knetsch and Davis (1966, p. 452) say: 'A source of error is a belief that outdoor recreation values have an aesthetic, deeply personal and even mystical value'. If money can represent the quality of paintings, sculptures and diamonds, why (ask economists) should it not also represent the quality of landscapes? The difficulty here lies in determining the monetary values of aesthetic aspects when no apparent market exists for them; however, this may not be an insuperable problem. An 'exchange' value for the environmental quality of an area might be estimated from the time and money that people are prepared to spend in travelling to that area. For instance, the money spent on travel by thousands of visitors to the Alps each year indicates something of the value of those mountains.

Value is related to scarcity and use. These factors determine how much a person is willing to sacrifice or trade in order to 'consume' something. As a person consumes more and more of a good, his desire for additional units of that good declines, and so he is less and less willing to spend on that good. This concept is illustrated by the demand function (Fig. 2).

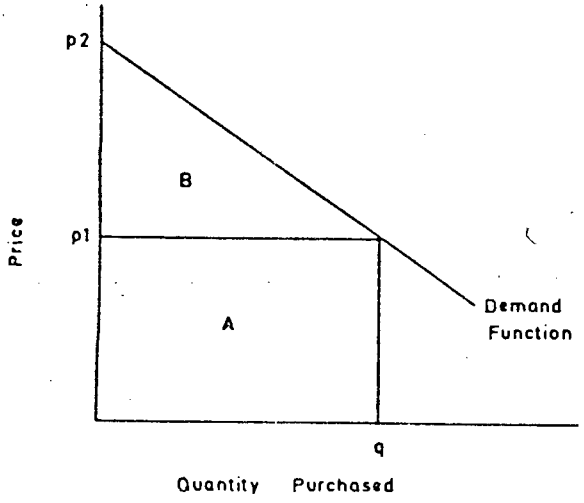

Fig. 2 Price-quantity relationship underpinning demand for a particular good

The area under the demand function represents the total satisfaction that a person can receive from a particular good. Area A represents the amount of money that the person has spent in purchasing q units of the good at unit-price p1 (price p1 x quantity q). However, the person has derived satisfaction from the consumption of the good beyond the satisfaction that is represented by area A; his additional satisfaction (area B) is referred to as 'consumer's surplus'. If the person is denied the opportunity to purchase and consume the good, he should be compensated for his loss of satisfaction. In order for the consumption to be equivalent to his total loss of satisfaction, the person should be paid an amount of money equal to area A plus area B. Thus, the total value of a natural amenity could theoretically be derived once a demand function for this amenity is produced. This demand function can be estimated crudely by taking 'price' as cost of travel to the amenity and 'quantity' as number of visitors. If the data required for this travel-cost method are not available, then opportunity-cost methods or questionnaire methods may be used, among others.

Opportunity-cost methods relate to the potential benefits that are necessarily lost through the choice of a particular development option. If revenue from a recreational area is maximised, then the earnings from this area would approximate to area A in Fig. 2, and would represent the opportunity cost resulting from a development project that destroys that area's recreational potential. Questionnaire methods are used to establish the amount of money that people would be willing to accept as compensation for the loss of amenities. This amount will correspond to area A plus area B, provided that questions are suitably phrased to prevent emotional bias on the part of the respondents.

Looking at the proposed Mupata Gorge scheme in particular, it is not possible to use a travel-cost method to establish a value for the area to be flooded by the dam since this part of Zimbabwe has been closed to tourists for several years. An opportunity cost method may be implemented by estimating the potential revenue that would be generated through alternative uses of the area (hunting/tourism, mining, agriculture). This method may be complemented by the derivation of a land value for the area on the basis of the compensation that was paid for Matetsi safari areas; also, information will be obtained on recent land sales and rentals of wilderness areas. It is hoped to use questionnaire methods to gain a further indication of compensation value for the area.

The construction of the Mupata Gorge Dam would give rise to some benefits (besides hydro-electric power) that would offset the opportunity costs to an unknown extent. Obvious benefits would be fish production, water-based recreation and the provision of a navigable stretch of water as part of a possible transport route to the sea as discussed in the next two articles in this issue of *Science News*. A great many questions related to these spin-offs would have to be investigated. Will the fish catch from Mupata Gorge Dam affect the market for fish from Kariba, or is there an insatiable demand for the protein? Would the new recreational amenity of the dam divert visitors from Kariba, Kyle, Ngezi etc? Would the navigational potential of the Zambezi be significantly enhanced by the dam, in view of the obstacles to shipping that still remain below Cabora Bassa? What demand is there for a shipping route down the Zambezi? Since a great deal of engineering work would be required to open the shipping route, would rail transport not be cheaper overall? . . .

An important consequence of the Mupata Gorge Dam would be the loss in perpetuity of wild area that is likely to appreciate in value as this type of amenity becomes scarcer and scarcer due to to development in other places. Referring back to Fig. 2, forces will act to shift the demand function outward over time, thus increasing the area below the curve. Such forces might include rising per capita income, population growth, growing appreciation of wilderness amenities as higher levels of education and affluence are reached, and greater ease of tourist travel due to transport innovations. It is intended to develop a simple model incorporating such factors; the model could be tested with a range of values for each factor to see how the worth of the area might change over time. Some of the aspects that are important in this issue cannot be quantified; an example is option value i.e. the satisfaction that people derive from knowing that a wild area is being conserved, even though they may never visit this area.

This discussion has centred on the Mupata Gorge Dam. This is because the scheme will be the most complex one in view of its threat to the character of the middle-Zambezi wilderness, and also because it appears to be the most likely only from the technical and financial points of view. A dam at Batoka Gorge would flood a small area, consisting of rocky slopes; a dam at Devil's Gorge would flood a large area, but this land is of low productivity. However, the latter dam would necessitate resettlement of people, with significant costs. Economic analyses of these two dams would certainly not be as difficult as the analysis of the Mupata Gorge Dam.

Overall, the economic analyses will provide facts and figures that can be included in the impact reports, and will also shed some light on the question of which project shows the greatest total benefit.

PANEL EVALUATION

The decision on whether/where a new dam should be built on the Zambezi is obviously the responsibility of the relevant authorities. However, it is felt that besides presenting a mass of information on likely impacts to these decision-makers, an attempt should be made to provide recommendations based on this information. The economic analyses will go a long way towards assisting in this task, but they cannot cover everything. The subjective aspects of the issue of development on the Zambezi are best handled by a method that incorporates a cross-section of ideas on these aspects (i.e. a 'thinktank').

A psychometric technique that might usefully be applied here is that of Thurstone's Model of Comparative Judgement. Here, a panel of interested and informed people would be identified (as large a panel as possible). Each person on the panel would be consulted separately and would be given the non-technical summaries of the environmental impacts of all the development options. These summaries would be presented randomly so that the person would not always know which project a particular impact stems from; this would be an attempt at reducing possible bias against a

project. The person would be asked to compare each impact in a pairwise fashion with each other impact, and to then indicate which impact is the most 'preferable' of the pair (in terms of that person's priorities on the issue). Once all the members of the panel have made these comparisons, it can then be established how often a particular impact was judged to be preferable to each of the other impacts. This information can be converted into percentages (of the total number of judgements) and then to Z- values (using a table relating percentages under a normal curve to standard scores). The Z- value for each impact is then an index of the desirability of that impact. The overall desirability of each project can be ascertained by adding up the Z-values of its constituent impacts, and the project with the highest total is then the 'most preferable' in the opinion of the panel.

This is the essence of the method, although its underlying rationale should be explained in order for it to be properly understood. The advantage of this method is that impacts do not necessarily have to be expressed in precise measurement units, as a person can make a judgement on the desirability of one impact in relation to another on the basis of purely verbal descriptons. The Z- values can be presented in the reports to which they relate, as an indication of 'public opinion' on the desirability of each impact. A useful addition to the Environmental Impact Statement would be a correlation between the findings of the economic analyses and the findings of the panel evaluation.

Obviously, the decision-makers are not required to follow the recommendations that are presented, but these should at least help them in getting the issue in perspective.

CONCLUSION

The methodology that has been outlined in this article represents an attempt to find a way of carrying out this important investigation with the minimum of bias, and with the use of local expertise. In this type of venture, interaction with as many interested people as possible is desirable, and the authors would appreciate any comments on their methodology.

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